



International Journal of
Environmental and Rural Development

Volume 13 Number 2

December 2022

International Society of Environmental and Rural Development



International Journal of Environmental and Rural Development

Official Journal of the International Society of Environmental and Rural Development

(Accessible from J-Stage, EBSCO, Google Scholar, CABI International, etc.)

Aims and Scope:

The International Journal of Environmental and Rural Development, IJERD, is an interdisciplinary journal concerning environmental and rural development research in the education for sustainable development, ESD. The IJERD is devoted to publishing peer-reviewed research article, review article and technical report in the fields of environmental and rural development, such as education for sustainable rural development, rural development, environmental management or agricultural systems. Every article or report in IJERD must be accepted by at least 2 reviewers and an editorial member.

The aims of IJERD are to publish the latest research development and achievements, to strengthen education systems, to promote cooperation in environmental and rural development and to contribute to the progress in sustainable development. The editorial board of this journal covers a variety of scientific disciplines.

Thematic Areas:

The following areas are envisioned in IJERD.

Education for Sustainable Rural Development:

Environmental Education, Food and Agricultural Education, Participatory Approach, Capacity Building, Community Empowerment, Agricultural Extension, etc.

Rural Development:

Marketing, Partnership, Value Added Product, Community Development, Access to Technology, Cultural Preservation, etc.

Environmental Management:

Bio-Diversity, Soil Degradation and Land Conservation, Water Quality Conservation, Deforestation and Sustainable Forest Management, Environmental Management, etc.

Agricultural Systems:

Organic Farming, Conservation Tillage, Mechanization, Irrigation and Drainage, Nutrient and Pest Management, Cattle Breeding, Agro-Forestry, Indigenous Technology, etc.

Infrastructural Systems:

Water Resource Development, Land Reclamation, Road Construction, etc.

Editorial Board:

Editor in Chief:

Prof. Dr. Machito Mihara, Tokyo University of Agriculture, Japan /
Institute of Environmental Rehabilitation and Conservation, Japan

Managing Editors:

Dr. Narong Touch, Tokyo University of Agriculture, Japan
Dr. Shinobu Terauchi, Institute of Environmental Rehabilitation and Conservation, Japan
Dr. Jeeranuch Sakkhamduang, Institute of Environmental Rehabilitation and Conservation,
Southeast Asia Office / Association of Environmental and Rural Development, Thailand

Editorial Advisory Board:

Prof. Dr. Mom Seng, Royal University of Agriculture, Cambodia
Dr. Insa Kuhling, University of Applied Sciences, Germany
Dr. Carlos Onan Tovar Mendoza, Honduras Embassy in Japan, Honduras
Prof. Dr. Nouredin Driouech, Mediterranean Agronomic Institute of Bari, Italy
Prof. Dr. Kiichiro Hayashi, Nagoya University, Japan
Prof. Dr. Kingshuk Roy, Nihon University, Japan
Dr. Yuri Yamazaki, Tokyo University of Agriculture, Japan
Prof. Dr. Merites M. Buot, University of the Philippines Los Baños, Laguna, Philippines /
UP Open University, Philippines
Prof. Dr. Salvador Catello, University of the Philippines, Philippines
Prof. Tomas Reyes, Jr. Bohol Island State University, Philippines

Dr. Julian Torillo, Jr. Bohol Island State University, Philippines
Dr. Venkatachalam Anbumozhi, International Centre for Trade and Sustainable Development,
Switzerland
Dr. Anchasa Pramuanjaroenkij, Kasetsart University, Thailand
Prof. Dr. Rajendra P. Shrestha, Asian Institute of Technology, Thailand
Dr. Somsak Srisontisuk, Khon Kaen University, Thailand
Dr. Vidhaya Trelo-Ges, Khon Kaen University, Thailand
Prof. Dr. Vo Quang Minh, Cantho University, Vietnam

Editorial Section in ISERD Secretariat:

Research Center, Institute of Environmental Rehabilitation and Conservation (ERECON)

2987-1 Onoji Machida-shi, Tokyo 195-0064, Japan
Tel/Fax: +81-42736-8972
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

Collaborated with

Association of Environmental and Rural Development (AERD)

93/64 Moo.3, Sinsab Village 2, Bungyeetho Sub-District, Thanyaburi District,
Pathum Thani 12130, Thailand
Tel/Fax: +66-2957-8064
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

Publisher of International Journal of Environmental and Rural Development:

Institute of Environmental Rehabilitation and Conservation (ERECON)

2987-1 Onoji Machida-shi, Tokyo 195-0064, Japan
Tel/Fax: +81-42736-8972
E-mail: hq-erecon@nifty.com
Webpage: www.erecon.jp

Contents

Chemical Characteristics of Natural Mineral Water from a Wellspring in the Ban Haubueng Community Forest, Nampong District, Khon Kaen Province, Thailand <i>Nuttira Kleawklahan and Chuleemas Boonthai Iwai</i>	1
Empowerment of Women: A Comparative Analysis of Experiences from Rural Communities in Ethiopia <i>Asres Elias, Kumi Yasunobu and Yuki Toyama</i>	5
Relation between the Level of Degradation and the Wind Speed Reduction Efficiency of Tree Windbreaks Systems in Ovche Pole Region, Macedonia <i>Ognen Onchevski, Teruaki Irie, Ivan Minchev and Machito Mihara</i>	13
Social Characteristics and Sustainability of Residents-Led Biological Monitoring in Japanese Agricultural Landscapes <i>Masayuki Nitta, Naohisa Nakashima, Mitsuru Ohira and Muneyuki Aoki</i>	19
Sensory Evaluation of Dried Fettuccine Pasta Enriched with Gotu Kola <i>Centella asiatica</i> <i>Charlene Eve L. Saligumba and Jean F. Nebrea</i>	26
Proposal of New Pickles to Improve Food Sanitation at Wet Markets in Cambodia <i>Sokly Sorm, Yoshiki Muramatsu, Daiki Oka, Yuri Tanioka Masataka Uchino, Shuki Muramatsu, Motoe Sekido Takahiko Nakamura, Toru Nakajima, Eiichiro Sakaguchi Shotaro Kawakami, Mari Arimitsu and Machito Mihara</i>	32
Cadmium Bioaccumulation in <i>Amaranthus spinosus</i> L. Grown in Contaminated Soil of Benguet Province, Philippines <i>Elizabeth T. Dom-ogen and Romeo A. Gomez, Jr.</i>	38
Effects of Vermicompost and Mineral Water on the Growth Parameters of the KDML 105 Rice Cultivar <i>Duangnapa saiyakit and Chuleemas Boonthai Iwai</i>	44
Benefits of Applying Microbial Fuel Cell Technology in Organic Farming for Sustainable Agriculture <i>Narong Touch and Takahiko Nakamura</i>	49
Evaluation of Soil Erosion Risk in the City of Cobija, Bolivian Amazonia Using RUSLE and GIS <i>Juan Uego Perez and Machito Mihara</i>	55
Effect of Adding Agricultural and Organic Lime on Soil Properties and Survival Rate of Pathogenic Bacteria (Coliform and <i>E. coli</i>) in Farmland Soils of Kampong Cham Province, Cambodia <i>Muy Leang Kim and Machito Mihara</i>	61
Product Formulation from a By-Product from the Production of Coconut - Based Food Delicacies <i>Maria Donna F. Buates and Chona C. Fullido</i>	69
An Evaluation of Consumers' Preference for the Organic Rice Commodity in Thailand <i>Nareerut Seerasarn and Serval A. Miller</i>	75
The Legacy of the Waternetwork from the Past: Characteristics and Types of the Covered Waterways in Tokyo <i>Ivana Angelova, Davisi Boontharm and Masami Kobayashi</i>	83
Awareness and Compliance of Corn Farmers to Good Agricultural Practices (GAPs) in Nueva Vizcaya, Philippines <i>Jane B. Bacani</i>	91

Evaluation of Sediment Trapping Capacity by Geotextile for Erosion Control	99
<i>Sarvesh Maskey, Takanori Kaneko, Hiromu Okazawa Antonio Perez Fuentes, Sachiko Watanabe, Kazuhiro Tazaki and Takahiro Sasaki</i>	
Estimation of Long-term River Discharge in Forested Watershed in Snowy Region by SWAT	105
<i>Shotaro Kikuchi, Hiromu Okazawa, Sarvesh Maskey Sergio Azael May Cuevas, Makoto Oba, Shogo Nakamura and Seiji Hayashi</i>	
Sustainability of the Implementation of Solid Waste Management: A Comparative Study	113
<i>Ma. Magdalena J. Bernales and Jake C. Malon</i>	
Disparity in Quality of Life and Education Attainment of Children within the Tea Sector: Case Study in Low-Country in Sri Lanka	119
<i>Yuko Fukuda and Eiji Yamaji</i>	
Agriculture Entrepreneurship on Youth: A Systematic Literature Review	127
<i>Fadhilla Izzaty Syaukat, Katsumori Hatanaka, Nina N. Shimoguchi and Ramadhona Saville</i>	
Comparison of Crop Surface Models and 3D Point Clouds by UAV Imagery on Estimating Plant Height and Biomass Volume of Pasture Grass	137
<i>Ke Zhang, Ayako Sekiyama, Hiromu Okazawa Yuri Yamazaki, Kiichiro Hayashi, Osamu Tsuji and Masahiro Akimoto</i>	



Chemical Characteristics of Natural Mineral Water from a Wellspring in the Ban Haubueng Community Forest, Nampong District, Khon Kaen Province, Thailand

NUTTIRA KLEAWKLAHAN

Office of Agricultural Research and Development Region 3,
Ministry of Agricultural and Cooperatives, Khon Kaen, Thailand

CHULEEMAS BOONTHAI IWAI*

Department of Soil Sciences and Environment, Faculty of Agriculture,
Khon Kean University, Khon Kean, Thailand
Email: chuleemas1@gmail.com

Received 21 February 2022 Accepted 22 April 2022 (*Corresponding Author)

Abstract This research aimed to analyze the chemical characteristics of natural mineral water from a wellspring in the Ban Haubueng Community Forest, Nampong District, Khon Kaen Province, Thailand. Physico-chemical properties and minerals status are important deciding factors in the assessment of water quality for water resource utilization. Therefore, the contamination of heavy metal and essential minerals from different locations within the Ban Haubueng community forest were evaluated. Water samples were collected in 2021 and then analyzed according to standard methods for heavy metal and the essential minerals; As, Pb, Cd, Zn, Cu, Hg, Ni, Mn, Zn, Fe, Se, Na, Si, and Ca through the use of Inductively Coupled Plasma Optical Emission Spectroscopy. In-house methods were also employed, based on EPA 3015 and microbial contamination; such as *Escherichia coli* via AFNOR Certificate Number 3 M 01/ 8-06/ 01 compared with ISO16649-2, and for *Salmonella* spp. by ISO 6579:2017. The results found that As, Pb, Cd, Zn, Cu, Hg and Ni as well as *E. coli* and *salmonella* were not detected in all water samples. Essential minerals including Si and Ca were detected in the mineral water samples at 7.61 ppm -7.64 ppm and 3.0 ppm-8.86 ppm, respectively. Therefore, we concluded that the mineral water has no heavy metal contamination and is safe from pathogenic microorganisms; *E. coli* and *Salmonella* spp. Moreover, other mineral elements present, like silicon may warrant further investigation for other purposes, such as agricultural production.

Keywords natural mineral waters, heavy metals, pathogenic microorganisms, water quality

INTRODUCTION

Water is very important for rural development and contributes significantly to people health. Water is an essential component of our food and contributes to many mineral nutrients. Its contribution to health is directly within households through food and nutrition, and indirectly as a means of maintaining a healthy, diverse environment. Fresh water is essential for agriculture, domestic use, and drinking purpose for human and animals. Water quality depends upon the chemical and biological characteristics of water. Therefore, human health as well as sustainable agricultural development will not be possible without availability of quality fresh water in adequate quantity (WHO, 1996).

The Ban Huabueng community forest has an area of 80 rai (1 rai= 1,600 square meters), and is represented by seven community forest committees. The area is characterized by sandy loam and characterized as a dry evergreen forest, most of the trees found are *Dipeterocapus alatus* Roxb. ex. G. Don, *Shorea obtusa* Wall. Ex Blume, *Shorea siamensis* Miq. *Hopea odorata* Roxb., *Ficus callose*. Community utilization of the forest has been for conducting ritual ceremonies and for the

benefits provided by the wellspring, at 100 and 91.2 percent, respectively (Phulawan, 2020). A wellspring in the Ban Huabueng community forest was found and used by villagers since 1899. Mineral water from wellspring is a natural water source, which farmers use for both consumption and agriculture. A quality assessment of the natural mineral water is, therefore, needed to ensure safe water consumption and for water resource management for villagers.

OBJECTIVE

The purpose of this research was to analyze the chemical and biological water characteristics of the natural mineral water from the wellspring in the Ban Haubueng community forest, Nampong District, Khon Kaen Province, Thailand.

METHODOLOGY.

The study area is Ban Huabueng which located at Moo 9, Sai Mun Sub-district, Nam Phong District, Khon Kaen Province, Thailand and founded in 1899, the village consists of a 62-rai residential area with a total of 157 households, an agricultural area of 883.24 rai, and a public area of 124 rai (1 rai= 1,600 square meters). The educational level was primarily at the elementary level, representing 46.0 percent. Agriculture was the primary occupation followed by various forms of general employment. The average number of household members was four people, with an average income of 44,734.51 baht per year, and the average life span in the Ban Huabueng community was 52.55 years.

The water samples were collected from different sites in plastic bottles, which were previously washed with detergents and HNO₃ acid and later rinsed with sampled water several times. Total 1.5mL of 2M HNO₃ was added to each 100mL samples (pH<3) for metallic ions determination to maintain the stability of the oxidation state of the various elements in solution and prevent precipitation (Singh et al, 2005).

Three samples from different sites consisting of a) mineral water from the community forest’s wellspring, b) mineral water from paddy fields, c) irrigation water, were collected and tested. The water samples were collected in June 2021 and then analyzed according to standard methods for heavy metal and essential minerals; including As, Pb, Cd, Zn, Cu, Hg, Ni, Mn, Zn, Fe, Se, Na, Si, and Ca through the use of inductively coupled Plasma optical emission spectroscopy (ICP-OES). In-house methods were also employed, based on EPA 3015 and microbial contamination, such as *E. coli* via AFNOR Certificate Number 3 M 01/8-06/01 compared with ISO16649-2, and for *Salmonella* spp. by ISO 6579:2017.



Fig. 1 The study area and water sampling sites

RESULTS

Heavy metal and other essential minerals from each sample location within the Ban Haubueng community forest were shown in Tables 1 and 2. The results found that As, Pb, Cd, Zn, Cu, Hg, Ni; as well *Escherichia coli* and *Salmonella* spp. were not detected in all water samples. Essential minerals, such as Si and Ca were detected in the mineral water at 7.61ppm-7.64 ppm and 3.0 ppm-8.86 ppm, respectively. Therefore, it can conclude that the natural mineral water from a wellspring in the Ban Haubueng Community Forest has no heavy metal contamination and safe from pathogenic microorganisms, like *Escherichia coli* and *salmonella* spp. (Tables 1, 2).

Table 1 Chemical characteristics (metal contents) of natural mineral water from the wellspring in Ban Haubueng Community Forest, Nampong District, Khon Kaen Province (unit:ppm)

Metal contents	Mineral water from wellspring in community forest	Mineral water in paddy field	Irrigation water	Standard ^a
Zn (ppm)	ND	ND	ND	1.00
Fe (ppm)	ND	0.84	0.03	1.00
Se (ppm)	ND	ND	ND	-
Na (ppm)	1.71	2.75	15.67	200 ^b
Si (ppm)	7.61	7.64	6.36	-
Ca (ppm)	3.0	8.86	28.31	-
As (ppm)	ND	ND	ND	0.10
Pb (ppm)	ND	ND	ND	0.05
Cd (ppm)	ND	ND	ND	0.01
Cu (ppm)	ND	ND	ND	1.00
Ni (ppm)	ND	ND	ND	0.10
Mn (ppm)	0.01	0.02	0.02	0.05

^a Water quality standard for surface water sources, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand

^b The World Health Organization, a drinking water guideline of 200 mg of sodium/L

Table 2 Analysis of pathogenic microorganisms (*Escherichia coli* and *Salmonella* spp.) in the water samples

	Pathogenic microorganisms	
	<i>E. coli</i> (cfu/g)	<i>Salmonella</i> spp. (in 25 grams)
Mineral Water from the wellspring	< 10	Not detected
Tap water in the village	< 10	Not detected
Irrigation water	< 10	Not detected

DISCUSSION

Heavy metals are known to be toxic, persistent within environmental settings, possibly bioaccumulated and concentrated in the biota and food chain, as well as containing carcinogenic metalloids (Hee et al., 2019). There are various sources, including natural and anthropogenic, of heavy metals in aquatic environments. Metals from anthropogenic sources such as industrial wastes, agricultural runoff, urban runoff, atmospheric deposition, and automobile emissions could be dispersed to the surface water via surface runoff or rain water. From this research, no toxic heavy metal contents were found in the natural mineral water from the wellspring in the Ban Haubueng community forest, Nampong District, Khon Kaen Province. But silicon and calcium, the mineral elements were found in the mineral water from community forest wellspring. This finding may be useful information for using this water resource in others purposes, such as agricultural production. The composition of the mineral water was analyzed and found several nutrients; for example, silicon, which is known for its role in alleviating the negative stress effects on numerous plant

species (Frew et al., 2018) and calcium that is good for plants. Silicon, as previously reported, applied with fertilizer increased grain and straw yield, plant height, number of tillers, number of panicles, and 1000-grain weight of rice (Pati et al., 2016; Cuong et al. 2017). The increased growth and yield of rice were influenced by its ability to reduce biological and physical stresses (Pati et al., 2016). The nutritional values of rice vary with different varieties, soil fertility, fertilizer application, and other environmental conditions (Verma, and Srivastav, 2017). Rice production has been done in this area. Therefore, rice grown with mineral water from wellspring in community forest could be a beneficial source of mineral supplements for people in the village.

CONCLUSION

We concluded that the natural mineral water from the wellspring in the Ban Haubueng community forest, Nampong District, Khon Kaen Province has no heavy metal contamination and is safe from pathogenic microorganisms (*Escherichia coli* and *salmonella* spp.). The water quality status of the natural mineral water from the wellspring in the Ban Haubueng community forest, Nampong District, Khon Kaen Province during the wet seasons is under Thailand Water Quality Standard in term of heavy metals and pathogen. This finding provides a scientific reference for protecting local aquatic ecosystem and managing water resources development in this community for the future.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the Office of Agricultural Research and Development Region 3, Ministry of Agricultural and Cooperatives, Khon Kaen, Thailand, and the Integrated Land and Water Resource Management Research and Development Center in Northeastern Thailand, Khon Kean University, Khon Kaen, Thailand.

REFERENCES

- Cuong, T.X., Ullah, H., Datta, A. and Hanh, T.C. 2017. Effects of silicon-based fertilizer on growth, yield and nutrient uptake of rice in tropical zone of Vietnam. *Rice Science*, 24 (5), 283-290, Retrieved from DOI <https://doi.org/10.1016/j.rsci.2017.06.002>
- Frew, A., Weston, L.A., Reynolds, O.L. and Gurr, G.M. 2018. The role of silicon in plant biology, A paradigm shift in research approach. *Annals of Botany*, 121 (7), 1265-1273, Retrieved from DOI <https://doi.org/10.1093/aob/mcy009>
- Hee, Y.Y., Suratman, S. and Aziz, A.A. 2019. Water quality and heavy metals distribution in surface water of the Kelantan River basin (Malaysia). *Oriental Journal of Chemistry*, 35 (4), Retrieved from DOI <http://dx.doi.org/10.13005/ojc/350402>
- Pati, S., Pal, B., Badole, S., Hazra, G.C. and Mandal, B. 2016. Effect of silicon fertilization on growth, yield, and nutrient uptake of rice. *Communications in Soil Science and Plant Analysis*, 47 (3), 284-290, Retrieved from DOI <https://doi.org/10.1080/00103624.2015.1122797>
- Pollution Control Department. 2010. Water quality standard for surface water. PCD, Thailand, Retrieved from <https://www.pcd.go.th>
- Singh, D., Chhonkar, P.K. and Dwivedi, D.S. 2005. Manual on soil, plant and water analysis. Westville Publishing House, ISBN 8185873267, New Delhi.
- Verma, D.K. and Srivastav, P.P. 2017. Proximate composition, mineral content and fatty acids analyses of aromatic and non-aromatic indian rice. *Rice Science*, 24 (1), 21-31, Retrieved from DOI <https://doi.org/10.1016/j.rsci.2016.05.005>
- World Health Organization. 2003. Health criteria and other supporting information. Guidelines for Drinking-Water Quality (Second Ed), Vol. 2, World Health Organization, Geneva.



Empowerment of Women: A Comparative Analysis of Experiences from Rural Communities in Ethiopia

ASRES ELIAS*

Faculty of Agriculture, Tottori University, Tottori, Japan

Email: asres@tottori-u.ac.jp

KUMI YASUNOBU

Faculty of Agriculture, Tottori University, Tottori, Japan

YUKI TOYAMA

United Graduate School of Agricultural Science, Tottori University, Tottori, Japan

Received 29 January 2022 Accepted 13 May 2022 (*Corresponding Author)

Abstract Empowering women and reducing gender disparities are key challenges of 21st century. This is more pressing in rural areas of developing countries like Ethiopia. The problem is prevalent in intra-household relationships. However, most initiatives of women empowerment have been transitory and externally imposed without considering structural causes of gender inequality hence they have been less effective. We reviewed and compared rural women's empowerment under widely occurring traditional systems versus community-led initiative, specifically the case of the Awra Amba community in northwest Ethiopia. The comparison was made on the bases of key indicators including division of labor, access to information, and resources, leadership and decision-making and gender-based violence. There exist number of studies assessing gender relations in rural areas under traditional systems. The studies showed that rural women have more workload involving both household and farm activities compared to men who are tasked to mainly outside home activities. Moreover, limited accesses to information, services and control over resources, low decision-making power, lack of opportunities to self-development such as education and training are key challenges to rural women. However, the above observed gaps seem to have been relatively tackled in the case of the Awra Amba community. This community owns a unique self-organized system with the goal of addressing socio-economic problems through the principle of egalitarianism. Woman's inferior position in the community is believed to be eliminated by destroying the traditional gender roles and patriarchal gender ideology. As a result, some of the community values and principles have been replicated to other Ethiopian rural communities through own initiated exchange visits. But the actual implementation of the community-led initiative in Awara Amba is not immune to criticism. Therefore, in-depth scientific research, and upscaling of successful community-led empowerment practices should be encouraged to understand how locally organized collective actions help to realize inclusive development.

Keywords community-led initiative, decision-making, division of labor, women empowerment, Ethiopia

INTRODUCTION

Gender Equality and Women's Empowerment (GEWE) is indispensable component for sustainable economic growth and poverty reduction (Global Health 50/50 and IFPRI, 2021; UN Women, 2018). It exists where women and men, boys and girls have equality in all aspects of life including, education, health, nutrition, access to economic assets and control over resources, and possessing equal decision power at all levels. However, persistent challenges such as unpaid workloads and lower recognition of women's work; an unequal balance of power in the home and community; lack of access to and control over resources; and gender-based violence remain significant barriers

to gender equality. On the other hand, if rural women had equal access to production factors, yields from their fields would increase by 20 to 30% total agricultural output by up to 4% in developing countries, that will lead to better child health and education, food security and improved nutrition (FAO, 2011; Alkire et al., 2013). In general, greater participation and empowerment of women in the home, community and organizations lead to more inclusive development and representative institutions, and build resilience and peace, which in turn contributes for development.

While promoting GEWE as one of the major pillars of the previous Millennium Development Goals (MDGs) and the current Sustainable Development Goals (SDGs), in many parts of the developing world, gender inequalities continue to be extreme. These gender inequality problems are particularly severe in Sub-Saharan Africa where population is expanding rapidly. For Sub-Saharan Africa to leverage its demographic dividend, it is vital to include all segments of society, including the poor, marginalized men and women into the development process. Without inclusive and transformative development, it is hard to ensure socio-economic development, enhance productivity and improve welfare of future generation in the region (World Bank, 2020). To curb the challenges of gender equality, many donors and programs implement instrumental approaches to address inequitable gender norms such as men's dominance in decision-making, constraints that limit women's access to resources and services, among others. However, these efforts often are transitory and imposed from outside while overlooking the significance of existing community-led practices, social norms and values. Unless structural causes of gender inequality are addressed, instrumental approaches alone cannot build empowerment and enhance resilience (Minne et al., 2018).

Ethiopia is one of the Sub-Saharan African countries which has adopted global agreements and endorsed country-specific laws and policies that are stated in the country's constitution Article 35, such as equality in matters related to employment, equality in acquisition and management of property, equal participation in policy and decision making, and right of women to plan their family (FDRE, 1995). The reforms on family code implemented in 2000 and the community-based land registration, undertaken since 2003 have shown progress little by little (Kumar and Quisumbing, 2015). However, there are still huge gaps and challenges in implementation that can be witnessed by the gender gap index that shows Ethiopia placed at 97th rank out of 156 countries (WEF, 2021). Ethiopia being a country characterized by traditional, conservative and patriarchy culture that ascribes a low status to women in all dimensions, however in some self-organized rural communities such as Awra Amba, women's inferior position in the society is believed to be eliminated by destroying the traditional gender roles and patriarchal gender ideology (Emirie and Teferi, 2013; Mengesha et al., 2015; Joumard, 2021). Thus, to understand these two contrasting phenomena that exist in one country, literature review and investigation of the present situation were conducted to identify areas for future research.

OBJECTIVE

This study reviewed existing literatures and compared gender roles and relations under widely occurring traditional systems versus community-led women empowerment initiative such as the case of the Awra Amba community in northwest Ethiopia.

METHODOLOGY

Literature Search Method

A systematic search of articles published in peer-reviewed journals, dissertations, reports, and books between January 2001 - December 2021 was conducted using Web of Science and Google Scholar databases. Particularly Google Scholar was used to search studies related to Awra Amba community (as most of the studies exist in master's thesis and report form). The keywords used were 'rural women', 'gender' and 'Ethiopia'. The specific time period was selected for two reasons; 1) to incorporate up to date literatures, and 2) as it aligns with the period when Awra Amba

became publicly known through Ethiopian Television documentary about the village aired in 2001 (Joumard, 2021; Østebø, 2021). The documentary narrated the story of a self-sustained and gender-equal community in contrast to the traditional gender-conservative society in Ethiopia.

The search results were vast. However, a review of the studies was made based on studies explicitly focus on gender roles and relations including division of labor, access to information, services and resources, leadership and decision-making role and gender-based violence in rural Ethiopia. Only studies that were a good fit with the research objective and accessible online were included. Besides, title, abstract and conclusion of each study were checked to decide the relevancy. Out of 124 articles accessed in Web of Science and 16 dissertations, articles and reports in Google Scholar, we only screened and used 23 studies. We did not conduct quantitative analysis rather main findings of the selected studies are qualitatively synthesized, summarized, and presented. As women's empowerment is hard to measure conceptually and contextually, the focus of this review paper is only to compare gender relations in a traditional versus community honored as a model for gender equality in published and unpublished literature, national and international media outlets, among others. However, it does not mean gender relations cannot show the situation of women empowerment. Gender relations are critical aspects of culture that shapes the way daily life is lived in the family and community as a result it can serve as a cornerstone for empowerment.

Description of Target Groups of the Study

The purpose of this section is to provide an overview of the target groups of this review paper, specifically: rural women in locations where traditional systems are commonly practiced, and Awra Amba community, where gender equality is advocated and implemented. This section can serve as a basis to understand the remaining parts of the paper.

Over 80% of Ethiopian women reside in rural areas, where households are engaged primarily in subsistence agriculture. In the countryside, women are integrated into the rural economy, which is often labor-intensive and demands a heavy physical force in agriculture and domestic chores. As in other traditional societies, in Ethiopia, a woman's worth is measured in terms of her role both as a mother and wife. Women are rarely perceived for their hard work, and most of the time a man decides in their lives and limits their access to resources and opportunities (Demissie and Abebe, 2017; Gebrehiwot et al, 2018). As a result of patriarchal gender ideology, most rural women are generally submissive to men.

Table 1 Characteristics of target groups

Characteristics	Women in the traditional system	Women in Awra Amba community
Demography	About 80% reside in rural areas	Consists of about 500 people
Livelihood	Subsistence farming	Agriculture, weaving, small trade, and tourism
Gender ideology	Patriarchal (conservative)	Non-patriarchal
Religion	Exist	Non-exist

Awra Amba is a small rural village in Ethiopia, comprises about 500 people (weaving cooperative community). It is located 73 km East of Bahir Dar in the Fogera district of South Gonder Zone, Ethiopia. The people share a strong ideology and culture, which differentiates them from other communities. Number of studies show the community advocates and have codified rules and regulations: gender equality, children's rights, solidarity, the golden rule (treat others as you would like to be treated yourself), the value of work, absence of religion or institutionalized religion, and democracy (Gelana, 2009; Teferi, 2013; Ambawu, 2015; Joumard, 2021). They believe in hard work and being good to all people.

The next section presents how the above two contrasting social norms that exist in one country have been devoted to ensuring gender equality through women's empowerment based on indicators mentioned in the first part of methodology section.

RESULTS AND DISCUSSION

Gender Based Division of Labor

Since the 1970s, there have been ongoing discussions over the ways in which gender roles in the home and outside are assigned and recognized. Division of labor, gender roles and inequality in a society depend on its cultural beliefs about the nature and social values of gender differences in competencies and traits (O'Connor, 2019). This fact is a common phenomenon in Ethiopia where gender roles and division of labor is dictated by cultural and social norms. Women are traditionally expected to work hard and are responsible for all reproductive and household related activities, on top of their active role in farm activities except ploughing which is considered as a man's task in Ethiopia (Elias et al., 2015; Badstue et al., 2020; Joumard, 2021). Women have greater workload than men but viewed as auxiliaries who provide labor (Petros et al., 2018; Badstue et al., 2020) and their workload is estimated between 13-17 hours a day, which is comparatively more than twice that of men (OECD, 2014; Elias et al., 2015; World Bank, 2020). As a result, women's workload (time poverty) is main disempowerment factor in agriculture and beyond (Petros et al., 2018; Belete and Melak, 2020). Generally, in rural areas of Ethiopia, women are solely responsible for household chores, while men are responsible for tasks outside the home. It is culturally dishonor for men to be involved in reproductive activities (domestic chores) (Gebrehiwot et al., 2018). Discriminatory social institutions/ norms and stereotypes on gender roles exacerbate unequal distribution of responsibilities and therefore, remain one of the constraints to ensure gender equality that in turn enable women to be active participants in social and economic development of rural areas.

Table 2 Brief summary of gender relations in traditional system and Awra Amba community

Indicators	Women in the traditional system	Women in Awra Amba community
Division of labor	-Gender based division of labor exist. -Women are traditionally responsible for all domestic chores on top of their active role in farming.	-Gender roles do not exist. -Men do domestic chores including childcare, cooking, etc. Women do productive activities and vice versa.
Decision making power and leadership role	-Women have nil to limited voice in decision making, participation and leadership role in household and public rural organizations.	-Women have the right to take leadership role and decision-making power and exercise it at both at household and community levels.
Access to and control over benefits of resources, information, and services	-Limited access to and control over resources, including land, and use of credit, improved technologies, education, and training.	Equal access to education, health services, possession, and control over benefits of resources including land and household assets.
Gender-based violence	-Nearly half of Ethiopian women experience lifetime GBV.	Their non-violent treatment of women makes them different from others.

Source; Authors compiled from reviewed literature

Contrary to the above facts, in Awra Amba community which has distinct gender relations, there is almost no marginalization and discrimination of women and gender-based division of labor. Nearly all reviewed studies revealed that gender roles and relations are guided by the principle of mutual understanding among all members of the community. The community rule and regulation states in its article 5 that both men and women must share equally all their responsibilities inside and outside the home (Joumard, 2021) they should share works on a strict basis of ability and efficiency guided by discussions and mutual understandings (Emirie and Teferi, 2013; Ambawu, 2015) both the Awra Amba females and males have androgynous and nontraditional gender role perception (Ebrie, 2015). However, according to Ebrie (2015) and Cherie (2012), the absence of stereotypic gender role is not the basic element of gender equality in Awra Amba, rather it is the result of active participation of women in decision-making and maintain shared equality of assumptions among themselves.

Women’s Decision-Making Power and Leadership Role

The Beijing conference agreement, known as the Platform for Action, named women in power and decision-making one of the 12 critical areas of concern. Though progresses have been made little by little in Ethiopia after the Family Code adopted in 2000, and currently 50% of the cabinet is occupied by women, but women still have far to go towards equal representation in power and leadership in general and rural areas in particular. According to Gebrehiwot et al. (2018); Petros et al. (2018) and Badstue et al. (2020), men have a dominant position in rural society, while women have nil to limited voice in decision processes at the household level, and participation and representation in public rural organizations. Generally, men are viewed as the primary farmers and controlling major decisions including land use, the use of credit, and control over income and expenditure. Furthermore, women’s right to participate in reproductive health decision ranges from 40-60% (Alemayehu and Meskele, 2017; Tadele et al., 2019).

Whereas in Awra Amba community, women have the right to take leadership role and decision-making power both at household and community levels (Emirie and Teferi, 2013; Ambawu, 2015). Their participation and representation rate in the development committee (the main administrative structure) which consists of about 15 sub-committees has increased from 36% in 2004 to 64% in 2011 to 70%, and to 81% in sub-committees in 2020. Though, it does not mean equality was achieved in the studied years, rather tremendous improvements have made in terms of women’s participation and representation in institutions found in the community (Joumard, 2021). Moreover, Ambawu (2015) depicted that the number and timing of children are decided by mutual understanding of both husband and wife; women also fully exercise their sexual rights with the absence of pressure and autonomous to access reproductive health services (Teferi, 2013). In general, traditional stereotypes that hinder women’s decision-making role have disappeared (Teferi, 2013). Human dignity and impartiality are fundamental values for women’s and men’s active participation in decision-making and democratic power relationship in Awra Amba (Mengesha, et al., 2015) relative to the traditional system that favors the superiority of men and restricts the rights of women in multiple dimensions.

Women’s Access to Resources, Information and Services

Eliminating barriers that prevent women from having the same access to education, economic opportunities and productive inputs can address structural, gender-based inequalities (Lea et al., 2018; UN Women, 2018). However, in many developing countries including Ethiopia, rural women have limited access to and control over a range of resources, including land, access to and use of credit, cash, improved technologies, information and extension services that are essential to increase their farm productivity and income (Elias et al., 2015; Demissie and Abebe, 2017; Petros et al., 2018; Badstue et al., 2020; World Bank, 2020). It is main disempowerment factor in agriculture at large and other income-generating activities in particular (Belete and Melak, 2020). Gebrehiwot et al. (2018) revealed that customary and traditional institutions and practices restrict women’s access to land, market and trading, resource related decision-making at the household and community levels.

However, in Awra Amba, men and women have the rights to involve in any economic activities to earn their own income and participate in social activities (Emirie and Teferi, 2013; Yassine, 2008). Women have equal access to health services, possession, and control over benefits of resources including land and household assets and other opportunities (Gelana, 2009; Endale, 2013; Ambawu, 2015). According to the reviewed literature, boys and girls have equal access to education. For instance, Joumard (2021) revealed that girls’ enrollment rate at university increased from 46% in 2013 to nearly 100% in 2020. There is no prioritization of son’s education over daughters. Moreover, women are economically independent and can engage in their own income generating activities other than the income earned from community’s share (Teferi, 2013). Women and men have equal access to and control over the benefits gained from land and non-land related resources (Ambawu, 2015). Besides, during divorce, women can equally share asset and property

acquired throughout marriage (Joumard, 2021) which is uncommon and source of dispute in other parts of rural Ethiopia.

Gender-Based Violence Against Women

Gender-based violence (GBV) is a serious violation of human rights and a life-threatening health problem globally. According to the WHO (2021), it is estimated that one in three women will have experienced GBV, and the incidence is particularly severe in developing countries including Ethiopia. A meta-analysis review by Kassa and Abajobir (2018) indicated that nearly half of Ethiopian women experience lifetime GBV including physical, sexual and psychological violence. Mainly women and girls in rural areas are victims of various harmful traditional practices such as wife-beating (Gurmu and Endale, 2017; Muche et al., 2014), early marriage, female genital mutilation (Demissie and Abebe, 2017), prioritize son's education over daughters' (Gelana, 2009), etc. On the other hand, Muche et al. (2014) and Deyessa et al. (2010) depicted that GBVs are acceptable and tolerable in rural than urban areas due to socio-cultural and traditional norms; mild consequences towards the person accountable to the offence; low education level, among others.

On the contrary, GBV is not acceptable and condemned in Awra Amba community. Their social norms and non-violent treatment of women make them different from the surrounding society (Teferi, 2013; Ambawu, 2015). Unlike their neighbor, women are not beaten; no discrimination towards single or divorced women (Yassin, 2008); marital relationship is solely based on free consent of the couples; sexual relations are considered a common good and not a shameful act to discuss about it (Joumard, 2021). As a result, women are free to deal with reproductive health issues. In general, Teferi (2013) explained this situation as a result of cultural values like truth, love, non-violence, and peaceful co-existence reinforced by the community's moral standards- "do as you would be done by", contributed to the internal and external peace processes in Awra Amba.

However, in a stark contrast to the above studies, a recent study conducted by Østebø (2021) criticizes the communities gendered exclusion tendency that comes due to false accusations. The author challenges the narratives of the communities' origin, especially on the viewpoint of religion, potential of power concentration and questioned the promotion of the community as a 'model to alleviate poverty'. But the author almost acknowledged the absence of gender-based division of labor. Though, the study is a thorough investigation of 'understanding the spread of policy models in a digital age' using Awra Amba as a case, yet the arguments and conclusions are based on generalized theoretical concepts that did not consider local contexts, exhaustive and balanced investigation of the two sides of the stories told by individuals. It requires further multidisciplinary quantitative and qualitative studies to refute and/or prove the conclusions made. On the other hand, according to Awra Amba community public relations (2020) there are about 9 communities replicating Awra Amba values and principles since 2004 to ensure gender equality and eliminate poverty. But to the best of our knowledge, there are no studies that investigate how the values and principles are replicated in other areas.

CONCLUSION

This review depicts that rural woman in developing countries like Ethiopia are still facing a multitude of empowerment-related challenges such as: gender-based division of labor that leads to more workload to women; lack of decision-making power and leadership role; poor access to resources and services including health and education; and frequent gender-based violence and its prevalence. Past efforts done to address these challenges often are transitory and imposed from outside while overlooking the structural causes of inequality embedded in values and social norms. These challenges, if not addressed, will remain bottlenecks to the UN's Sustainable development goals to ensure all people enjoy peace and prosperity by 2030. However, community-led gender sensitive initiatives like the experience of Awra Amba can have potential to unlock these challenges, even if such initiatives are not immune to criticism (e.g., Østebø, 2021). More study on

their role for local and global development has been largely overlooked and this merits future study. Hence, in-depth multidisciplinary research remains important to understand how community-led women empowerment practices help to realize inclusive development.

REFERENCES

- Alemayehu, M. and Meskele, M. 2017. Health care decision making autonomy of women from rural districts of southern Ethiopia, A community based cross-sectional study. *International Journal of Women's Health*, 9, 213-221, Retrieved from DOI <https://doi.org/10.2147/IJWH.S131139>
- Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G. and Vaz, A. 2013. The women's empowerment in agriculture index. *World Development*, 52, 71-91, Retrieved from DOI <http://dx.doi.org/10.1016/j.worlddev.2013.06.007>
- Ambawu, S. 2015. Women's decision-making rights in the household, A case study on Awra Amba Community in Fogera Woreda. Master Thesis, Center for Human Rights, Addis Ababa Univ., 110, Retrieved from <http://213.55.95.56/handle/123456789/16892>
- Badstue, L., Van Eerdewijk, A., Danielsen, K., Hailemariam, M. and Mukewa, E. 2020. How local gender norms and intra-household dynamics shape women's demand for laborsaving technologies, Insights from maize-based livelihoods in Ethiopia and Kenya. *Gender, Technology and Development*, 24 (3), 341-361, Retrieved from DOI <https://doi.org/10.1080/09718524.2020.1830339>
- Belete, B. and Melak, S. 2020. Impact of small-scale irrigation technology on women empowerment in Amhara National Regional State of Ethiopia. *Cogent Economics and Finance*, 8 (1), Retrieved from DOI <https://doi.org/10.1080/23322039.2020.1837440>
- Cherie, T. 2012. A study of the nature of group communication among Awra Amba community members in promoting social change. Master Thesis, School of Journalism and Communication, Addis Ababa University, Ethiopia.
- Demissie, S. and Abebe, A. 2017. Gender and rural livelihood in the Lake Tana Basin. In Stave, K., Goshu, G. and Aynalem, S. (Eds.), *Social and Ecological System Dynamics*, AESS Interdisciplinary Environmental Studies and Sciences Series, Springer, Retrieved from DOI https://doi.org/10.1007/978-3-319-45755-0_19
- Deyessa, N., Berhane, Y., Ellsberg, M., Emmelin, M., Kullgren, G. and Högberg, U. 2010. Violence against women in relation to literacy and area of residence in Ethiopia. *Global Health Action*, 3 (1), Retrieved from DOI <https://doi.org/10.3402/gha.v3i0.2070>
- Ebrie, S. 2015. Gender role perception among the Awra Amba community. *American Journal of Applied Psychology*, 3 (1), 15-21, Retrieved from DOI <https://doi.org/10.12691/ajap-3-1-4>
- Elias, A., Nohmi, M., Yasunobu, K. and Ishida, A. 2015. Does gender division of labor matters for the differences in access to agricultural extension services, A case study in north-west Ethiopia. *Journal of Agricultural Science*, 7(1), 138-147, Retrieved from DOI <https://doi.org/10.5539/jas.v7n1p138>
- Emirie, G. and Teferi, E. 2013. Gender relations in access to and control over resources in Awra Amba community of Amhara Region. *Ethiopian Journal of the Social Sciences and Humanities*, 9 (2), 1-36, Retrieved from <https://www.ajol.info/index.php/ejossah/article/view/90022>
- Endale, A.A. 2013. The place of children through the lens of generational and gender relationships in Awra Amba community, northern Ethiopia. Master's Thesis, Norwegian Centre for Child Research (NOSEB), Faculty of Social Science and Technology Management (SVT), Norwegian University of Science and Technology (NTNU), Norway, Retrieved from <https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/269116>
- Federal Democratic Republic of Ethiopia. 1995. Federal Negarit Gazeta of the Federal Democratic Republic of Ethiopia, Retrieved from <https://ethiopianembassy.be/wp-content/uploads/Constitution-of-the-FDRE.pdf>
- Food and Agricultural Organization (FAO). 2011. *Women in agriculture, Closing the gender gap for development*. Rome, Italy.
- Gebrehiwot, M., Elbakidze, M. and Lidestav, G. 2018. Gender relations in changing agroforestry homegardens in rural Ethiopia. *Journal of Rural Studies*, 61, 197-205, Retrieved from DOI <https://doi.org/10.1016/j.jrurstud.2018.05.009>
- Gelana, G. 2009. Women cultural role expectations and their participation in functional adult literacy programs, A comparative study of Awra Amba and Ater Midir communities, South Gonder Zone. Master's Thesis, Addis Ababa University, Ethiopia.
- Global Health 50/50 and International Food Policy Research Institute (IFPRI). 2021. 2021 global food 50/50 report, A review of the gender and equity-related policies and practices of 52 organizations active in the

- global food system. *Global Health* 50/50, Washington, D.C., USA, Retrieved from DOI <https://doi.org/10.2499/p15738coll2.134569>
- Gurmu, E. and Endale, S. 2017. Wife beating refusal among women of reproductive age in urban and rural Ethiopia. *BMC International Health and Human Rights*, 17 (6), Retrieved from DOI <https://doi.org/10.1186/s12914-017-0115-5>
- Joumard, R. 2021. Awra Amba, A utopia between myth and reality. Research Report, University Gustave Eiffel, France, Retrieved from <https://hal.archives-ouvertes.fr/hal-03199059v2>
- Kassa, G.M. and Abajobir, A.A. 2018. Prevalence of violence against women in Ethiopia, A meta-analysis. *Trauma Violence Abuse*, 21 (3), 624-637, Retrieved from DOI <https://doi.org/10.1177/18752483882205>
- Kumar, N. and Quisumbing, A.R. 2015. Policy reform toward gender equality in Ethiopia, Little by little the egg begins to walk. *World Development*, 67, 406-423, Retrieved from DOI <https://doi.org/10.1016/j.worlddev.2014.10.029>
- Lea, D., Valerie, M and Reyes, S. 2018. Gender justice in resilient development, Sharing program learning from Africa, South Asia and Central America. Oxfam, UK.
- Mengesha, S.K., Meshelemiah, J.C.A. and Chuffa, K.A. 2015. Asset-based community development practice in Awramba, northwest Ethiopia. *Community Development*, 46 (2), 164-179, Retrieved from DOI <https://doi.org/10.1080/15575330.2015.1009923>
- Minne, V., Reyes, S.S. and Doumenjou, L. 2018. In practice, Gender justice in resilient development, Sharing program learning from Africa, South Asia and Central America. Oxfam GB for Oxfam International, UK.
- Muche, A.A., Adekunle, A.O. and Arowajolu, A.O. 2017. Gender-based violence among married women in Debre Tabor Town, northwest Ethiopia, A qualitative study. *African Journal of Reproductive Health*, 21 (4), 102, Retrieved from DOI <https://doi.org/10.29063/ajrh2017/v21i4.11>
- O'Connor, C. 2019. The origins of unfairness, Social categories and cultural evolution. Oxford University Press, ISBN 978-0-19-878997-0, UK.
- Organization for Economic Co-operation and Development (OECD). 2014. Unpaid care work, The missing link in the analysis of gender gaps in labour outcomes. OECD Development Centre, Retrieved from https://www.oecd.org/dev/development-gender/Unpaid_care_work.pdf
- Østebø, M.T. 2021. Village gone viral, Understanding the spread of policy models in a digital age. Stanford University Press, ISBN 9781503614529, California, USA.
- Petros, S., Abay, F., Desta, G. and O'Brien, C. 2018. Women farmers' (Dis) empowerment compared to men farmers in Ethiopia. *World Medical and Health Policy*, 10 (3), 220-245, Retrieved from DOI <https://doi.org/10.1002/wmh3.280>
- Tadele, A., Tesfay, A. and Kebede, A. 2019. Factors influencing decision-making power regarding reproductive health and rights among married women in Mettu rural district, south-west Ethiopia. *Reproductive Health* 16, 155, Retrieved from DOI <https://doi.org/10.1186/s12978-019-0813-7>
- Teferi, E. 2013. The role of gender equality in promoting peace and development, The case of Awra Amba community in Fogera Woreda of Amhara National Regional State. *Anthology of Peace and Security Studies*, Retrieved from <https://www.africportal.org/publications/anthology-of-peace-and-security-studies-volume-4/>
- United Nations Entity for Gender Equality and the Empowerment of Women. 2018. Turning promises into action, Gender equality in the 2030 agenda for sustainable development report. UN Women, USA.
- World Bank. 2020. Ethiopia poverty assessment, Harnessing continued growth for accelerated poverty reduction. World Bank, Washington, D.C., USA.
- World Economic Forum (WEF). 2021. Global gender gap report 2021, Retrieved from <https://www.weforum.org/reports/global-gender-gap-report-2021/>
- World Health Organization (WHO). 2021. Devastatingly pervasive, One in three women globally experience violence. Joint News Release, Retrieved from <https://www.who.int/news/item/09-03-2021-devastatingly-pervasive-1-in-3-women-globally-experience-violence>
- Yassin, S.M. 2008. The work traditions their contribution rural development, in Awra Amba community, northern Amhara region, Ethiopia. Master Thesis, Mekele University, Ethiopia, Retrieved from <https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/3960>



Relation between the Level of Degradation and the Wind Speed Reduction Efficiency of Tree Windbreaks Systems in Ovche Pole Region, Macedonia

OGNEN ONCHEVSKI

*Graduate School of Agro-Environmental Science, Tokyo University of Agriculture, Japan
Email: ognenoncevski@hotmail.com*

TERUAKI IRIE

Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

IVAN MINCHEV

*Hans Em-Faculty of Forest Sciences, Landscape Architecture and Environmental Engineering,
University of Ss. Cyril and Methodius-Skopje, North Macedonia*

MACHITO MIHARA*

*Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: m-mihara@nodai.ac.jp*

Received 16 January 2022 Accepted 20 May 2022 (*Corresponding Author)

Abstract Ovche Pole is an agricultural region in Macedonia with dry climatic conditions characterized by low precipitation and high ambient temperatures during the growing period as well as prevailing winds that are present considerable time of the year. During the 1950s series of measures have been implemented to improve the agriculture productivity in the region. One of the measures taken was the establishment of tree windbreaks (field shelterbelts) aimed to reduce wind velocity and protect shelter crops. Ever since they become essential elements for the regional landscape, performing many important ecosystem functions. As far as authors' knowledge, so far there are no scientific studies that investigated the performance of the tree windbreaks in Ovche Pole-research area of this study. To fill the gap of scientific data, this study examines the relation between wind reduction efficiency of tree windbreaks with their level of degradation in that area. Optical porosity is used as a proxy for quantitative description of the level of degradation of the structure of the tree windbreaks. To this aim, field measurements for wind velocity and optical porosity (OP) were done on 3 (three) windbreaks sections. Photogrammetry method was used to determine the porosity at each windbreak section. Wind velocity field measurements were done with two handheld cone anemometers. The windspeed reduction efficiency was assessed by comparing the windspeed at the windward side with the windspeed at 3 points on the leeward side. The results show that the level of degradation is significantly related with the relative windspeed at distance of 30m and 60m from the tree line at the leeward side.

Keywords windbreaks, windspeed reduction efficiency, optical porosity, Ovche Pole region, North Macedonia

INTRODUCTION

Ovche Pole is an agriculture region in Macedonia with dry climatic condition characterized by low precipitation and high ambient temperatures during the growing period as well as year-round prevailing winds. The region is part to the semi-arid agriculture zone and sub-humid agriculture zone of the country (Aksoy et al., 2020). Northern winds are most dominant, blowing throughout the entire year, with an average frequency of 188% and an average speed of 4.6 m/sec. North-western winds have an average frequency of 127% and an average speed of 3.9 m/sec, blowing

throughout the entire year, but mostly in June and August. The third most frequent are the southern winds, with an average frequency of 66% and an average speed of 2.4 m/sec. (Evolving DOO, 2016). During the 1950's series of projects were taken to improve the agriculture productivity in the region. One of the activities was the establishment of tree windbreaks. The tree windbreaks were planted on a surface of 555.66 ha (Forest public enterprise, 2011). The trees rows are 10 m wide row in rectangle grid that formed agriculture parcels that are approximately 1000 m in length and 250 m width. Tree windbreaks are planted in southwest to northeast direction perpendicular to direction of the prevailing northwest winds. Today, much of the initial area is lost and certain areas are degraded because of illegal cutting done by the local population. Depending on the level of degradation, different sections of the tree wind brake systems have different wind speed reduction efficiency. The ability of windbreak to fulfill its wind protection function in landscape is given by its external and internal structure. The external structure is defined by width, height, shape, and orientation. The internal structure is given by the amount and arrangement of branches, leaves, and trees or shrubs trunks (Brandle et al., 2004). The most used descriptor of internal structure for artificial windbreaks has been porosity which is a simple ratio of perforated area to total area (Heisler and Dewalle, 1988). Height of the windbreak and porosity of windbreak are main parameters used to explain the windspeed reduction efficiency (Brandle et al., 2004; Helfer et al., 2009; Středová et al., 2012; Řeháček et al., 2017; Kučera, 2020). The windbreak porosity is classified as real (aerodynamic) and optical.



Fig. 1 Tree windbreaks in the research area showing its width is 10 m

Note: Taken by Onchevski in August 2021

Aerodynamic porosity is defined as the ratio between the average wind speed measured on the windward side of windbreak and the average speed in open space. Since aerodynamic porosity is difficult to define, the parameter of optical porosity (OP) is mostly used. For the evaluation of windbreak efficiency, optical porosity (OP) is determined by using the photogrammetry method (Kučera, 2020). Although, there is a linear relationship between windbreak efficiency and optical porosity; this connection can be influenced by several external characteristics of tree windbreaks (Wu et al., 2018). Therefore the objective of this study is see the relation between the level of degradation of the tree windbreaks and optical porosity and relate this parameter with the windbreak efficiency to protect the agriculture land from negative effects of prevailing wind.

METHODOLOGY

Study Area and Measuring of Wind Speed

Windbreak efficiency was analyzed on three windbreaks sections near the village of Erdzelija in the region of Ovche Pole. The agricultural field are located on around 3.5 km from village with latitude 41°51'18.45"N and longitude 22° 0'50.12"E.

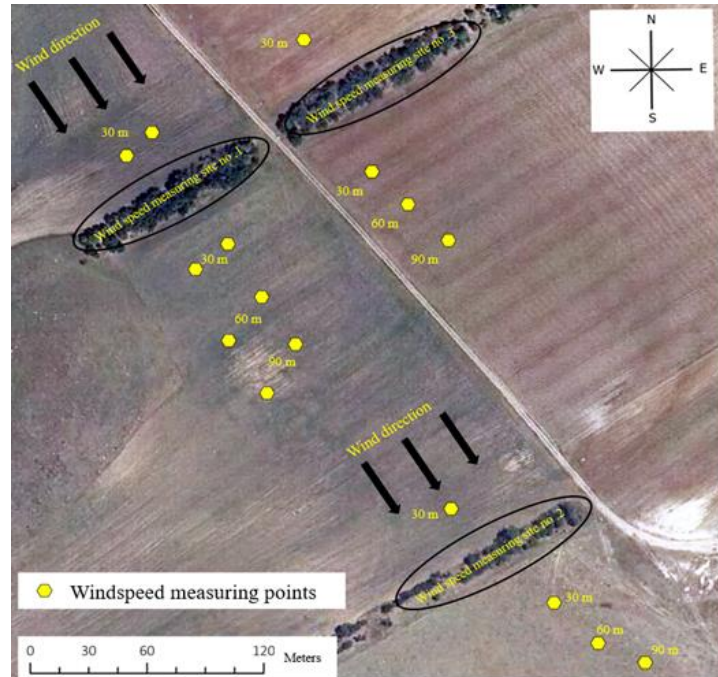


Fig. 2 Satellite photo showing research sites and windspeed measuring points

Averagely the tree windbreak sections are 6 m high and 10 m wide, however the level of degradation was different. To analyze the windspeed reduction efficiency, between 18 and 26 August 2021 at each tree windbreak section wind speed was measured on one point at the windward side and at tree points on the leeward side. Windward measuring point was set 30 m from the tree line and the leeward measuring points were set on 30 m, 60 m, and 90 m from the tree line. Windspeed was measured with two handheld cup anemometer type (Sato Tech AM-4257SD) fixed 1m above the ground, measurements were taken every 5 seconds. On the windward side windspeed was measured continuously for 6 hours during, however on the leeward side the first two hours was used for windspeed measuring at the first point (30 m distance), second two hours for measuring at the second point (60 m distance) and the last 2 hours for measuring at the third point (90 m distance).



Fig. 3 Setting up wind speed measuring equipment

*Top left corner showing the cup anemometer type used for recording the windspeed
Note: Taken by Onchevski in August 2021*

Optical Porosity- Level of Degradation of Tree Windbreaks

In addition to the windspeed measurements, the optical porosity was analyzed for each windbreak section. Optical porosity of windbreak was described by terrestrial photogrammetry method as the value of the optical porosity from the photo documentation of the windbreak at the time of field measurement. Each section was photographed with iPad Pro 12MP, *f*/1.8 aperture camera from the leeward side of the windbreaks at a 30 m distance from the windbreak on 1.5 m ground. Photogrammetric analysis was done using GIMP (version 2.10.28), AutoCAD and Excel software. At first, all photos were scaled in AutoCAD and then graphically processed to black and with binary image, where vegetation was highlighted and assigned in black against the background assigned in white. Histogram tool was used to calculate the exact number of black (= vegetation) and white(= background) pixels. The value of optical porosity was calculated as distribution of the white (background) pixels expressed as percent value. The higher the value of OP, the lower the vegetation distribution and windbreak effectiveness to reduce windspeed.

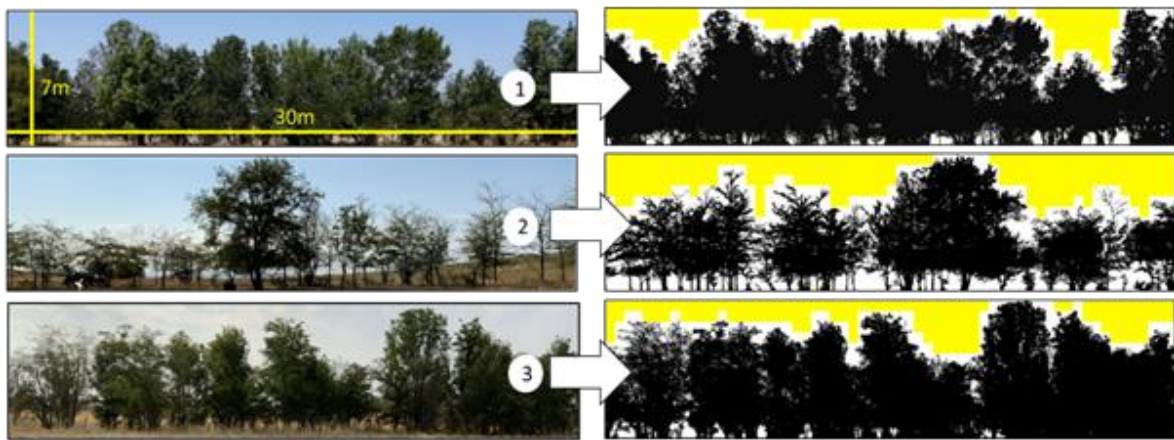


Fig. 4 Photos indicating tree windbreak measuring sites before and after pixel processing
Measuring site no.1 on the top, measuring site no.2 in the middle, and measuring site no.3 in the bottom

RESULTS

Optical Porosity

Analysis showed that site number 2 has the OP value of 35.8% which is highest, while site number 3 has lowest OP value of 16.57 %. Site number 1 has OP of 18.23%, value that is close to value of site number 3. The results of optical porosity (OP) analysis are presented in Table 1.

Table 1 Optical porosity of tree windbreak measuring sites

Site no.	Black (foreground) pixels	White (background) pixels	Optical porosity
1	4774038	1064042	18.23%
2	3289752	1834230	35.80%
3	4751115	943361	16.57%

Wind Speed Reduction Efficiency

The first wind speed measurements at site no.1 (Fig. 4) showed that this tree windbreak section can significantly reduce the windspeed coming from the windward side. At the leeward side at 30 m distance there is a reduction of 54%, at 60 m distance there is a reduction of 25% and at 90 m distance reduction of 8%. Expressed as relative windspeed, at 30 m distance the wind velocity is

46% of wind at the windward side, at 60 m the velocity is 75% of the velocity of windward side and at 90 m the wind speed is 92% of the windspeed at the windward side. The second measurements show similar trend in windspeed reduction efficiency. In this time, at 30 m distance the wind velocity is 47% relative to the windward side, at 60 m the velocity is 72% of the velocity of windward side and at 90 m the windspeed reached the same value (100%) as the incoming wind. Table 2 shows the relative windspeed at each site at the different measuring distances.

Table 2 Windspeed reduction related to different optical porosity and distance to tree line

Tree windbreak site no.	Optical porosity background pixels (%)	Relative windspeed (%)		
		30 m	60 m	90 m
1 (first measuring)	18.23%	46%	75%	92%
1 (second measuring)	18.23%	47%	72%	100%
2	35.80%	74%	95%	98%
3	16.57%	40%	78%	96%

Correlation results showed that optical porosity and windspeed reduction is significantly correlated for the measuring points at 30 m and 60 m distance from the tree windbreak, however at 90 m distance there was no correlation. For the 30 m distance measuring point the correlation coefficient (r) is high with a value of 0.993 and with a 99% level of significance ($p < 0.01$). For the 60 m measuring point correlation coefficient (r) is 0.95 and the level of significance of 90% ($p < 0.10$). These results confirm other authors' research conclusions that optical porosity is linearly connected with wind speed reduction efficiency and can be reliable measure for evaluation of windbreak efficiency (Brandle et al., 2004; Helfer et al., 2009; Středová et al., 2012; Řeháček et al., 2017; Wu et al., 2018; Kučera, 2020).

Table 3 Relation between optical porosity and windspeed reduction efficiency

	Anemometer position (leeward side) 1 m above ground		
	30 m	60 m	90 m
Measurements	4	4	4
Correlation coefficient (r)	0.993	0.950	0.292
P-value	0.007	0.05	0.708
Level of significance	$p < 0.01$	$p < 0.10$	n/a

CONCLUSION

Research results presented in this chapter shows that tree windbreaks systems in the research area play key role in buffering the negative effect of the prevailing winds. Having in mind that significant windbreak area was lost and existing are under threat of degradation, it is important that existing tree windbreaks systems are protected from degradation, degraded areas should be restored, and new tree windbreaks should be expanded to other areas. Another conclusion coming from the results is that optical porosity (OP) is a reliable measurement that can describe the wind speed reduction efficiency and level of degradation of windbreaks in the research area. This indicate that optical porosity can be used as guidance for maintenance and management of existing tree windbreaks as well as for guidance when establishing new windbreak areas. As recommendation optical porosity of the windbreaks should be maintained between 15-20%. At the degraded windbreak sections with optical porosity higher that 20%, to fill the internal voids and space, interplanting new trees is recommended. New planted trees should be species that can thrive in the local conditions and provide multiple functions such as: nitrogen fixation, fruits, pollen for honey, medicines and other NTFP. Some of the possible tree species are *Elaeagnus angustifolia* (Eng. Russian olive), *Ziziphus jujuba* (Eng. Chinese date), *Quercus* spp. (Eng. Oaks), *Cornus mas* (Eng. Cornelian cherry), *Prunus Amygdalus* (Eng. Almond), *Prunus cerasifera* (Eng. Cherry plum) and others.

REFERENCES

- Aksoy, E., Arsov, S., Mincev, I. and Fang, C. 2020. Agro-ecological, Atlas of the republic of North Macedonia. FAO, Rome, Retrieved from <https://www.fao.org/3/ca7519en/CA7519EN.pdf>
- Brandle, J.R., Hodges, L. and Zhou, X.H. 2004. Windbreaks in North American agricultural systems. *Agroforestry Systems*, 61, 65-78.
- Evolving, DOO. 2016. Environmental impact assessment study on construction of a wind farm in Bogoslovec, municipality of Sveti Nikole and municipality of Shtip. Technical No. 01-EIA-16.
- Heisler, G.M and Dewalle, D.R. 1988. Effects of windbreak structure on wind flow. *Agriculture, Ecosystems and Environment*, 22-23, 41-69, Retrieved from DOI [https://doi.org/10.1016/0167-8809\(88\)90007-2](https://doi.org/10.1016/0167-8809(88)90007-2)
- Helfer, F., Zhang, H. and Lemckert, C. 2009. Evaporation reduction by windbreaks, Overview, modelling and efficiency. Urban Water Security Research Alliance Technical Report, No. 16.
- Kučera, J., Podhrázská, J., Karásek, P. and Papaj, V. 2020. The effect of windbreak parameters on the wind erosion risk assessment in agricultural landscape. *Journal of Ecological Engineering*, 21 (2), 150-156, Retrieved from DOI <https://doi.org/10.12911/22998993/116323>
- Řeháček, D., Khel, T., Kučera, J., Vopravil, J. and Petera, M. 2017. Effect of windbreaks on wind speed reduction and soil protection against wind erosion. *Soil and Water Research*, 12 (2), 128-135. Retrieved from https://www.agriculturejournals.cz/publicFiles/45_2016-SWR.pdf
- Středová, H., Podhrázská, J., Litschmann, T., Středa, T. and Rožnovský, J. 2012. Aerodynamic parameters of windbreak based on its optical porosity. *Contributions to Geophysics and Geodesy*, 42 (3), 213-226, Retrieved from DOI <https://doi.org/10.2478/v10126-012-0008-5>
- Wu, T., Zhang, P., Zhang, L., Wang, J., Yu, M., Zhou, X. and Wang, G. 2018. Relationships between shelter effects and optical porosity, A meta-analysis for tree windbreaks. *Agricultural and Forest Meteorology*, 259, 75-81, Retrieved from DOI <https://doi.org/10.1016/j.agrformet.2018.04.013>



Social Characteristics and Sustainability of Residents-Led Biological Monitoring in Japanese Agricultural Landscapes

MASAYUKI NITTA*

Toyo University, Kawagoe, Japan

Email: nitta061@toyo.jp

NAOHISA NAKASHIMA

Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Japan

MITSURU OHIRA

Tokyo University of Agriculture and Technology, Fuchu, Japan

MUNEYUKI AOKI

Toyo University, Kawagoe, Japan

Received 14 February 2022 Accepted 6 June 2022 (*Corresponding Author)

Abstract Biological monitoring in agricultural landscapes is conducted as part of local residential activities in some rural regions. Such survey activities are expected to have social effects such as environmental education and community empowerment, in addition to biodiversity monitoring. However, it remains unclear how residents conduct the biological surveys, assess the sustainability of the activities, and identify potential effects on their communities. This study aims to clarify the social characteristics of biological surveys by residents and examine the sustainability of the activities. The survey reports of 37 local activities in aquatic habitats of rice-farming landscapes in the city of Utsunomiya in the Tochigi Prefecture, Japan, were collected. By using the reports, the basic activity features of the surveys, such as the number and the attributes of participants, the time, dates and sites of the surveys, were examined, and the local organizations were clustered based on the similarities of the features. Finally, the number of detected species by the biological surveys and the contents of group discussions, which were held after the surveys, in each cluster were compared. The results showed that the number of participants of the biological surveys ranged from 11 to 235, and the participation rate of children was high at 94.1%, while the participation rate of experts was low at 20.6%. Our main findings are as follows: (1) the residential organizations with invited biological experts detected the highest number of species. (2) the cluster with no children tended to have no discussion. In conclusion, our findings imply that expert participation is vital for finding species and that child participation is essential for sustainability of this biological monitoring.

Keywords biological survey by residents, citizen science, agricultural environments, paddy fields

INTRODUCTION

In Japan, the "Survey on Lives in Paddy Fields" has been conducted nationwide by the Ministry of Agriculture, Forestry and Fisheries (MAFF) and the Ministry of the Environment (MOE) since 2001 to assess the current status and changes in ecosystems around rice paddies. The survey conducted by the government has a problem with the number of sites and is qualitative and quantitative limited in survey items due to cost and work resources (Watabe et al., 2011). Meanwhile, in the prefectural government alone, local residents have a movement to conduct surveys of living things. In Tochigi Prefecture, as a measure of Improvement in Land, Water and Environment Conservation, "Survey on Lives in Paddy Fields and Surrounding Environment" has been mandatory for organizations implementing the payment grant of multifunctionality since 2007.

By having residents take the initiative in conducting the survey, various effects can be expected, from educational effects to regional revitalization (Mineta et al., 2008; Tanaka et al., 2008; Mizutani et al., 2014): solving economic problems, arousing interest in nature, raising environmental awareness, restoring local communities, and increasing willingness to participate in environmental conservation activities.

Quantitative elucidation of the relationship between paddy fields biodiversity and the efforts of the survey with local residents by using survey data will contribute to the formation/reformation of local communities and the conservation of biodiversity.

OBJECTIVE

This study aims to clarify the social characteristics of residents-led biological monitoring in Japanese agricultural landscapes from the viewpoints of activity features and examine the sustainability of the survey activities.

METHODOLOGY

Target Area

Target area is the city of Utsunomiya, Tochigi Prefecture in Japan. In this study, we used the secondary data from the community-based biological survey conducted in 2018. 37 residential organizations in Utsunomiya City conducted this survey in rice paddies, surrounding farm ditches, and reservoirs.

Data Collection

In this study we collected secondary data; the data were the survey reports collected by Utsunomiya City in 2018 with a specific format used in the "Survey on Lives in Paddy Fields and Surrounding Environment". Table 1 shows an example of a part of the sheets.

Table 1 An example of the survey sheets used in the biological survey by the local residents in Utsunomiya City in 2018

Subjects	Specific explanations about the survey	
Basic information	Name of the activity organization, date of survey, an outline of participants, survey location, number of years since infrastructure development, the design of the farm ditch, flow velocity, presence of vegetation in the ditch.	
Captured species	Paddies	Species name and the captured number of each species regarding birds, butterflies, dragonflies, amphibians, reptiles, fishes, shellfishes, insects, water plants
	Farm ditches	Species name and the captured number of each species regarding amphibians, fishes, shellfishes, insects, water plants
	Reservoirs	Species name and the captured number of each species regarding amphibians, fishes, shellfishes, insects, water plants
Discussions	Participants' ideas on the results of the survey, participants' ideas on the conservation environments in their rural area.	

Source: Guideline of "Survey on Lives in Paddy Fields and Surrounding Environment" by Tochigi Prefecture

The report has a discussion part that describes the participants' ideas and/or exchange of opinions on the biological survey or plan of the communities through the applicable events after finishing the capture of species surrounding the environment.

Under the multifunctional payment grant system implemented by Tochigi Prefecture, grant management organizations are established in each region, mainly by farmers, and the biological

surveys are conducted under the direction of these residential organizations. The organizations are only required to conduct this survey and submit the report. Therefore, the specific survey methods (participants, location, time, methodology, timing and awareness of ecosystem conservation, etc.) are vary depending on the organization.

Data Analysis

First, in order to clarify the basic features of the residents' survey activities, five items were selected, tabulated, and organized as follows: 1) the number of participants in the survey activities; 2) attributes of the participants (the breakdown of the attributes is non-organization member farmers, non-farmer local residents, children under high school age, other local organizations, and biological experts); 3) survey sites (paddy field, farm ditch, and reservoir) and survey timing; 4) contents of the after-survey discussion; 5) presence of photographic records.

Second, cluster analysis with ward's method was conducted to categorize and analyze the organization characteristics according to the similarity of the activities features in the above five items. Relationships between survey features and detected species and group discussion were compared between each category obtained by the cluster analysis. Based on this result, the issues for sustainable biological monitoring were discussed by focusing on the participant attributes.

RESULTS AND DISCUSSION

Basic Activity Features of Biological Surveys by Residents

According to city officials and the participatory observation by the authors, the survey was conducted according to the following procedure: firstly, participants received an explanation and some cautions from an organizer of the residential organizations at the beginning of the survey. Then, the participants spread out in paddies or ditches, capturing creatures with nets or hands for about an hour or above, and collected the captured species in buckets and other containers.

The number of participants in the survey activities was relatively large over many organizations (57 participants in average, 11 participants at minimum and 235 participants at maximum). Eight organization didn't mention the number of participants in the reports and the largest group of participants was between 21 and 60 participants, accounting for about 46% (Fig.1). Regarding the attributes of the participants, 34 organizations provided a breakdown of the attributes of the participants and three organizations did not. Fig. 2 shows the ratio of participation in the survey by each of the participant attributes ($n = 34$). Of the 34 organizations that described the attributes of the participants, ten organizations (29.4%) had non-member farmers participating, and 24 organizations did not. The number of organizations in which non-farmer local residents participated was 29 (85.3%), and they did not participate in was five. Seven organizations (20.6%) invited biological experts and 27 organizations did not.

In order to examine the relationship between the number of participants and the number of attributes of participants, single regression analysis was conducted on this data; as the result, no relationship was found between the number of attributes and the number of participants ($R^2 = 0.04$). This result supports that the number of participants does not necessarily correlate with the diversity of their attributes. The ratio of organizations that involved children and non-farmer local residents in their surveys to the total number of organizations was more than 80% (94.1% for children and 85.3% for non-farmer residents, Fig.2), suggesting that local residents thought this event would have some positive impacts to equip children with environmental education. However, the participation of biological experts was only less than 20%, and we can conclude that the attendance of experts to the residential biological survey is not shared.

As for the date, time and survey sites, 36 organizations stated the survey date and time in the reports, and one organization did not. Two of 36 organizations conducted the survey twice, at different times of the year. All 36 organizations conducted the survey at farm ditch. In the case of paddy fields, 18 organizations (50.0%) investigated, and about three organizations (8.3%) surveyed

reservoirs. Fig. 3 shows the frequency of the first survey timing of the 36 organizations by survey sites (farm ditch, paddy and reservoir). Survey timing shows similar trend between farm ditch and paddy: almost surveys were conducted during the irrigation season (from April to early October) and the most surveys were conducted during a month from mid-July to mid-August. During this period, the water flow of farm ditch is high, the paddy fields are irrigated, and it is favorable timing for farmers because the busy rice-planting season had passed. For these reasons, it is likely that most surveys at farm ditch and paddy were conducted from mid-July to mid-August. The frequency of survey at paddies was relatively lower than that at farm ditches. It is assumed that the reason for this is that many organizations found it difficult to conduct surveys in the rice paddies and allow children to enter because the paddies are privately owned and the rice plants are growing around July and August. Considering several surveys were conducted in end of October to beginning of November, the biological surveys were conducted during the irrigation period when the water flow of farm ditch is plentiful, and either after rice planting (mid-July to mid-August) or during the rice harvesting period (October to November). The survey at reservoir was conducted at mid-July and end of November. Because reservoirs are water storage facilities, they are often waterlogged throughout the year, so the timing of the surveys was likely not affected by the agricultural cycle.

Regarding the contents of the after-survey discussion, following is the list of examples of three ways to describe the discussion held by participants with each other after the survey:

1. general contents such as impressions,
2. motivation such as re-evaluation and re-recognition for their communities or the surrounding environment (e.g., "I want to make efforts in conservation activities to coexist with other lives while cherishing the nature of the region"),
3. future prospects such as specific countermeasure plans for environmental education.

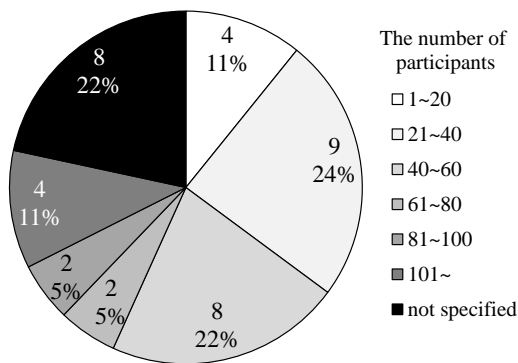


Fig. 1 Frequency of the number of participants (n = 37 organizations)

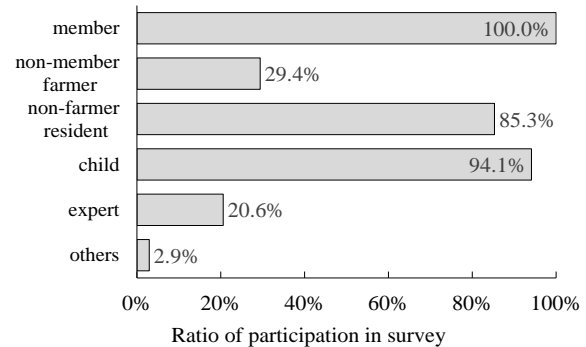


Fig. 2 The attributes of the participants (n = 34 organizations)

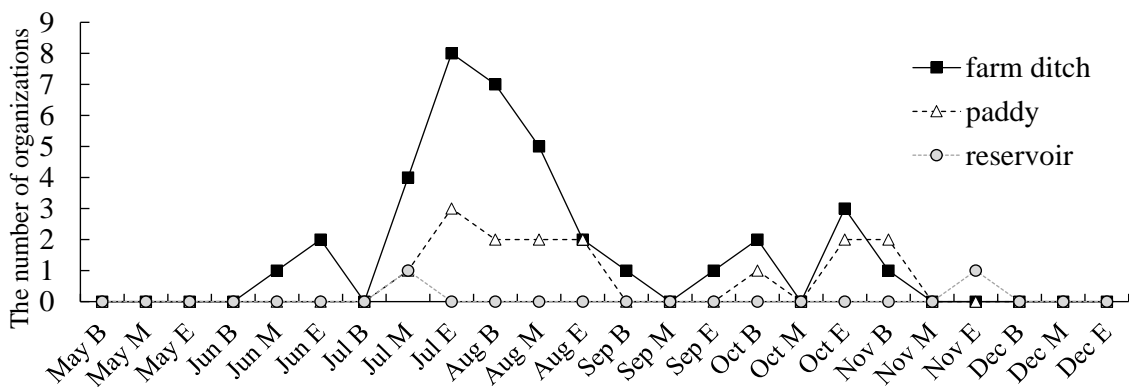


Fig. 3 Frequency of the first survey timing of 36 organizations by survey sites

The group discussions, including parents and children, were held after the survey. A typical example is that the survey organizers served lunch to participants and sat around inside or outside near the paddy fields. They had a conversation on the above three topics. 35 organizations wrote down the memo, contents, or the results of their discussions, and two organizations did not.

Relationships between Activity Features of Surveys and Detected Species and Group Discussion

In the cluster analysis, based on the analysis results in the previous section, we selected 15 items that impacted the residential biological survey from the social aspect, including the attributes of participants, survey times, and photographic records. The number of participants was excluded from the analysis for reliability reasons because of the high variability in values compared to the other variables. Accordingly, the 34 organizations’ data which completed all items were used in the analysis and three organizations’ data were excluded. The result of cluster analysis allowed us to distinguish the following characteristics among each organization (Fig. 4, Table 2).

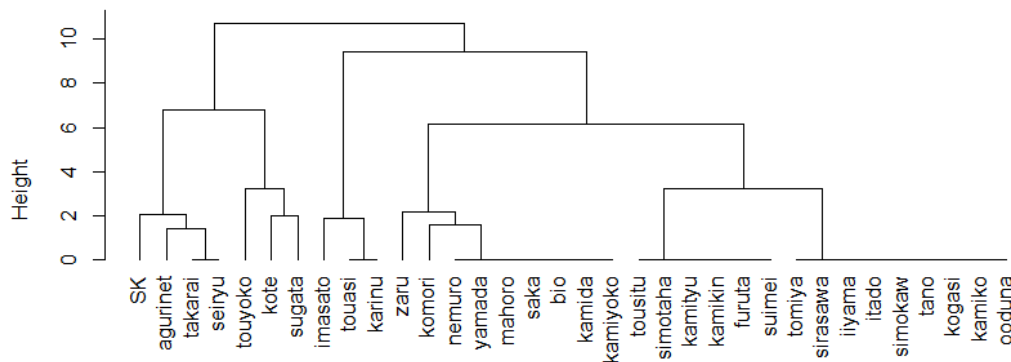


Fig. 4 The classification of the organizations

The texts on the horizontal axis represent the name of the organizations. The classification was pruned at the height of five.

Table 2 The details of the cluster classification and described characteristics

No.	Characteristics	Type	Score of discussion	Detected species
Class 1	Children attended, non experts attended, all documents submitted, survey one time, one or two attributes.	Complete document type	3.0	8.3
Class 2	Children attended, non experts attended, survey one time, almost one attribute.	Children participate type	2.4	10.0
Class 3	Children attended, experts attended in some case, survey two times, two or three attributes.	Multiple surveys type	3.3	12.0
Class 4	Children attended, experts attended, survey one times, two or three attributes.	Multi-attributes type	2.3	12.8
Class 5	Non children attended, non experts attended, survey one times, no attribute.	Non-child participate type	1.7	8.3

(1) Complete document type: no inadequacies in the documentation, photographs of the captured species, and a location map that explicitly describes the survey points were submitted. (2) Children's participate type: characterized by children's participation but not experts. (3) Multiple surveys type: The difference from the previous group, class 2, is that the survey was conducted multiple times throughout the year. This type was also characterized by children's participation, while experts might or might not attend the events. (4) Multi-attributes type: children and experts participated, and the attributes of the participants were diverse. (5) Non-child participate type: children and experts do not participate.

Table 2 shows that the average discussion scores of the organizations with children participating (3.0 of class 1, 2.4 of class 2, 3.3 of class 3 and 2.3 of class 4; 2.8 in average) were higher than that of the organizations without children (which was 1.7 of class 5). In addition, the organizations surveyed multiple times were more likely to include both child and expert, and had the highest discussion scores (3.3). Children's participation (resulting in increasing the number of surveys) indicated a high level of interest in the survey of natural lives in the community environment, leading to more active discussions.

The group with the highest number of species captured also had experts participating (Table 2). The number of species got the highest is not because the actual number of species captured was high, but instead because the captured lives could be identified at the species level when experts were present in the survey.

Issues for Sustainable Biological Monitoring

In this section, the issues for sustainable biological monitoring are discussed based on the results described so far.

The first is the lack of collaboration with experts. Only seven organizations out of 37 (around 19%) confirmed cooperating with biological experts. Considering that the clustered group with the highest number of species captured had experts participating, having experts participate at least once in every organization will be necessary to improve the quality of biological surveys. In general, it remains concerns about the accuracy of data collected by non-experts (Crall et al. 2011; Gardiner et al. 2012). With a guidance from experts, surveys can be conducted efficiently (Bonter and Cooper, 2012), and experts can be expected to give comprehensive advice and learning opportunities for children about the local environment based on the species habitat conditions. Survey method is also relevant for data quality (Lewandowski and Specht, 2015); for example, species photos and other information such as species features of color, voice and so on, are important to identify the species later. Taking species photos and stock correct information by matching the captured species with its name will also help the communities to figure out their environment ecosystem in the future (Kosmala et al., 2016).

Our cluster analysis results indicate that the residential biological survey, especially those with children, positively impacted communities' attitudes toward their environment (Table 2). According to Asah and Blahna (2012), the participation of non-experts is most motivated by personal and social benefits such as education and social interaction with other members rather than environment-related reasons. In the case of our study, the survey was discussed among the adult participants from the child's perspective, such as they want to continue to participate next year because the survey was a good experience for their children, and they wanted to protect their surrounding environments for their kids. Furthermore, the survey group without children did not discuss the prospect of their survey (Table 2). This implies that the participation of children has a role not only to deepen the contents of discussion which are held after the surveys, but also for the motivation of adult participants. The residential biological survey is considered to rouse interest in nature and increase motivation to participate in environmental conservation activities (Mizutani et al., 2014; Eberhardt et al., 2022), and our findings also followed their results. We showed that residential participation, especially when they include children, would shape community-wide conservation activities (Knafo and Galansky, 2008; Hartley et al., 2015) by promoting an understanding of their local environment and the resulting sustainable surveys.

CONCLUSION

We clarified the features of the residents' survey activities and examined the relationship between the features and the detected species and the contents of discussion which were held after the surveys. The group with invited biological experts detected the highest number of species. When children attended the discussion, participants tended to discuss their future prospects of activities,

leading to the sustainability of the biological survey by local residents. These results support that the participation of experts and children are recommended for sustainable biological monitoring.

The remaining problem is that only a few organizations mentioned a specific vision for environmental education in their discussions. Of the 35 organizations that recorded their discussions, only six organizations (17%) described their future prospects. Few concrete descriptions of future prospects based on the results of the discussions meant the influence of this survey on their communities was still unclear. For a countermeasure, when discussing the results of biological surveys, it would be helpful to prepare quantitative data on the survey results and maps of the species habitat status to serve as indicators for local communities. The discussion content should be broadened to include comments from experts and specific future perspectives on the nature of the survey and the community.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number 19H04317 and by the grant for a young researcher group, Japanese Society of Irrigation, Drainage and Rural Engineering in 2019.

REFERENCES

- Asah, S.T. and Blahna, D. 2012. Motivational functionalism and urban conservation stewardship, Implications for volunteer involvement. *Conservation Letters*, 5 (6), 470-477.
- Bonter, D.N. and Cooper, C. 2012. Data validation in citizen science, A case study from Project FeederWatch. *Frontiers in Ecology and the Environment*, 10, 305-307.
- Crall, A.W., Newman, G.J., Stohlgren, T.J., Holfelder, K.A., Graham, J. and Waller, D.M. 2011. Assessing citizen science data quality, An invasive species case study. *Conservation Letters*, 4 (6), 433-442.
- Eberhardt, A.L., Ward, L.G., Morrison, R.C., Costello, W.J. and Williams, C. 2022. Connecting science and community, Volunteer beach profiling to increase coastal resilience. *Continental Shelf Research*, 242, 1-10.
- Gardiner, M.M., Allee, L.L., Brown, P.M., Losey, J.E., Roy, H.E. and Smyth, R.R. 2012. Lessons from lady beetles, Accuracy of monitoring data from US and UK citizen-science programs. *Frontiers in Ecology and the Environment*, 10 (9), 471-476.
- Hartley, B.L., Thompson, R.C. and Pahl, S. 2015. Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin*, 90 (1-2), 209-217.
- Knafo, A. and Galansky, N. 2008. The influence of children on their parents' values. *Social and Personality Psychology Compass*, 2 (3), 1143-1161.
- Kosmala, M., Wiggins, A., Swanson, A. and Simmons, B. 2016. Assessing data quality in citizen science. *Frontiers in Ecology and the Environment*, 14, 551-560.
- Lewandowski, E. and Specht, H. 2015. Influence of volunteer and project characteristics on data quality of biological surveys. *Conservation Biology*, 29 (3), 713-723.
- Mineta, T., Ashida, T. and Ishida, K. 2008. New tool for recognition of the environment, "Survey on lives in paddy fields and surrounding environment" by farmer. *Journal of Rural Planning Association*, 27 (3), 125-131.
- Mizutani, M., Nansai, Y. and Kobori, T. 2014. Practices and outcomes of people participatory survey on paddy waters creatures. *Water, Land and Environmental Engineering*, 80 (1), 11-14.
- Tanaka, H., Satou, T., Nagayama, M., Koumoto, T., Yamaguchi, T. and Kawashima, H. 2008. Survey of biotic distribution and diversity in paddy irrigation canals through public participation. *Water, Land and Environmental Engineering*, 76 (7), 625-630.
- Watabe, K., Takemura, T., Mori, A., Koizumi, N., Matsumori K. and Saito, G. 2005. Evaluation of fish habitat potential using census of organisms in paddy fields, Japan. *Water, Land and Environmental Engineering*, 79 (12), 935-940.



Sensory Evaluation of Dried Fettuccine Pasta Enriched with Gotu Kola *Centella asiatica*

CHARLENE EVE L. SALIGUMBA*

Bohol Island State University Main Campus, Tagbilaran City, Bohol, Philippines
Email: charleneeve.saligumba@bisu.edu.ph

JEAN F. NEBREA

Bohol Island State University Main Campus, Tagbilaran City, Bohol, Philippines

Received 28 February 2022 Accepted 13 June 2022 (*Corresponding Author)

Abstract The use of gotu kola in food and beverages has increased over the years due to its beneficial and nutritional properties. The intent of this study is for the public utilization of the gotu kola and its improvement. It further investigates the sensory evaluation of dried fettuccine pasta enriched with gotu kola *Centella asiatica* among the three treatments in terms of aroma, color, taste and texture and to determine if there was a significant difference among the three treatments. This study used the experimental-descriptive research design employing a self-made modified questionnaire as a main tool in gathering the data through 4-point modified Hedonic scale for the level of liking. The data gathered were tabulated using the weighted mean and ANOVA to determine the significant difference in the respondent's liking among the three treatments. There was a total of 85 respondents composed of 55 selected food technology experts (25 instructors handling food technology and food related subjects and 30 students taking Master of Arts in Teaching Vocational Education major in Food Technology) and 30 consumers. The findings revealed that treatment 3 was "like very much" while, treatments 1 and 2 were "like moderately". The result showed there was a significant difference in the level of liking of the dried fettuccine pasta in three treatments. Thus, the researcher recommended to utilize gotu kola as a potential ingredient to enrich the pasta for possible income generating project for extension activities.

Keywords gotu kola, sensory evaluation, fettuccine pasta

INTRODUCTION

Filipinos are known to be passionate food lovers; they always search for those good snacks where it is delicious and healthy. Herbs hit it perfectly! These luscious leaves-parsley, mint, oregano, gotu kola and the like- not only add enticing aroma, fresh flavor and vivid green color to food but also have remarkable health benefits (Krieger, 2017).

In the Philippines, manufacturers of food use herbs in their production that turns the food more appealing and nutritious. One example of herbs present in this country is the Gotu Kola with a scientific name *Centella asiatica*. Gotu Kola is a small, slender, umbelliferous creeping plant. It acts as an alternative tonic, an agent which produces gradual beneficial change in the body, usually by improving nutrition, without having any marked specific effect and without causing strange clearing. Gotu Kola also prevents anxiety and stress which boost immune system (Stuart Jr., 2017). It has been proven to have many benefits in the body. It helps boost cognitive function, treat Alzheimer's disease, helps reduce anxiety and stress, acts as an antidepressant, improves circulation and reduce swelling, helps ease insomnia, helps reduce appearance of stretch marks, promotes wound healing, and minimize scarring, helps relieve joint pain and have a detox effect (Wilson, 2017).

According to Pharmacological Review on *Centella asiatica*: A Potential Herb Cure-all (2010) proved that gotu kola has been used as medicinal herbs since it does not contain any caffeine and

has not been shown to have stimulant properties. In this view, this study is optimistic to pursue in making something new out of the gotu kola to extend its importance as a medicinal herb and, at the same time, remedial snack food. But, more importantly, the intent of this study is also to catch the attention of the public that is averse to herbs. That is why pasta is to be made mixed with a prime substantial gotu kola.

OBJECTIVE

The study primarily aims to create a new variety of dried fettuccine pasta enriched with gotu kola which is abundant in the locality and this will be assessed to determine its sensory evaluation in terms of aroma, color, taste and texture.

METHODOLOGY

The study was an experimental and descriptive research using *Single-group* design in which it involves a single treatment with two or more levels. The experimental design was used in determining the different formulations in order to come up with a quality result of the study as to the sensory attributes of dried fettuccine pasta enriched with gotu kola. While the descriptive design with the aid of questionnaire using the modified 4-point Hedonic scale to investigate the sensory attributes and level of liking in terms of aroma, color, taste and texture and the shelf life of the three treatments which vary in the measurement of blended gotu kola. In harvesting the gotu kola, the researcher is careful enough to select the finest leaves both young and mature leaves together with its stem since they contain vital nutrients. The researcher got the gotu kola source at Loon, Bohol in which it is where the gotu kola herbs can be found in a domesticated area where it is a moist place and safe environment. After gathering the herbs, the researcher bought the other ingredients in the local market. And prepare the needed ingredients, tools, materials, and equipment in making the dried fettuccine pasta. The ingredients were separated and measured accurately with the proper use of tools and equipment. All the tools and equipment used were cleaned, sanitized and in good condition. The researcher formulated the recipes in three treatments; Treatment 1 is the pasta with 25 grams of fresh gotu kola, Treatment 2 is the pasta with 50 grams of fresh Gotu Kola, Treatment 3 is the pasta with 75 grams of fresh Gotu Kola.

The study was conducted at six BISU Campuses namely: BISU Main Campus, Balilihan Campus, Bilar Campus, Calape Campus, Candijay Campus, and Clarin Campus. The purposive sampling method was used to determine the participants. It involved 85 respondents composed of 55 selected food technology experts (25 instructors handling food technology and food related subjects and 30 students taking Master of Arts in Teaching Vocational Education major in Food Technology) and 30 consumers.

RESULTS AND DISCUSSION

In observing the shelf life of dried fettuccine pasta enriched with gotu kola, the researcher used two ways to identify the shelf life of the dried fettuccine pasta. The researcher put the pasta in sealed food containers and placed it in a refrigerator and a room to test how many days the pasta lasted in refrigerated and room temperature condition.

Table 1 reflects the shelf life of dried fettuccine pasta enriched with gotu kola in three (3) treatments. As illustrated in Table 1 in refrigerated condition, from day 1 to day 2, the three treatments were no changes occurred and were safe for human consumption. However, on day 3 changes occurred as to its aroma, color and texture. Aroma became unpleasant, texture became soft and lighter color. Therefore, on day 3, all three treatments were spoiled and not safe for food consumption.

Table 1 Shelf life of dried fettuccine pasta with enriched gotu kola in refrigerated condition

Treatment	Number of days	
	Day 1-2	Day 3
T1	No changes occurred	Unpleasant aroma, lighter color, and not safe for food consumption
T2	No changes occurred	Unpleasant aroma, lighter color, and not safe for food consumption
T3	No changes occurred	Unpleasant aroma, lighter color, and not safe for food consumption

Table 2 Shelf life of dried fettuccine pasta with enriched gotu kola in room temperature condition

Treatment	Number of weeks			
	Week 1-2	Week 3	Week 4	Week 5
T1	No changes occurred	Lighter color	Lighter color and milder aroma	Molds appeared and no longer safe for consumption
T2	No changes occurred	Lighter color	Lighter color and milder aroma	Molds appeared and no longer safe for consumption
T3	No changes occurred	No changes occurred	Lighter color and milder aroma	Molds appeared and no longer safe for consumption

Another way to get the shelf life of the dried fettuccine pasta enriched with gotu kola is in room temperature condition. As shown in Table 2 in room temperature condition, from day 1-2 week, the three treatments were no changes occurred. However, on week 3, the researcher observed that the color of the treatment 1- 25 grams of gotu kola as well as the treatment 2- 50 grams of gotu kola slightly faded and lighter. But for treatment 3- 75 grams of gotu kola, the color remained and there were no changes occurred. On week 4, the observation of the three treatments was lighter color and milder. Lastly on week 5, the three treatments, has molds appeared and no longer safe for consumption. The measurements of gotu kola added to the pasta, were one of the factors that affected the shelf life of the pasta. In room temperature condition, the three treatments got damaged on week 5. But in refrigerated condition it was easily damaged on the 3rd day. Thus, the lesser the blended fresh gotu kola, the longer its shelf life. The more the blended fresh gotu kola, the earlier to spoil.

Table 3 Nutrition facts analysis of dried fettuccine pasta enriched with gotu kola

Analysis	T1	T2	T3
Crude ash, g/100g	1.22	1.11	1.50
Crude fat, g/100g	3.80	3.82	3.41
Moisture, g/100g	14.9	12.6	14.8
Crude Protein, g/100g	13.6	14.0	13.2
Carbohydrates, g/100g	66.5	68.5	67.1
Calories, cal/100g	355	364	352

Table 3 shows the nutritional facts analysis of the dried fettuccine pasta enriched with gotu kola among the three treatments. In order to get the nutritional value of the three treatments, the researcher submitted the required sample size to First Analytical Services and Technical Cooperatives (F.A.S.T) Laboratories. They identified the basic requirement of the Food and Drugs Administration (FDA) which is moisture, ash, fat, protein, calories, and carbohydrates. The result implies that in every 100 grams of each treatment, it contains adequate energy and nutrients for the maintenance of health and well-being of people (Das, 2011).

Table 4 Sensory attributes of dried fettuccine pasta enriched with gotu kola in terms of aroma, color, taste and texture

Sensory attributes	Treatment 1		Treatment 2		Treatment 3	
	Mode	Description	Mode	Description	Mode	Description
Aroma	2	Slightly Pleasant	3	Pleasant	3	Pleasant
Color	2	Light Green	3	Green	4	Dark Green
Taste	3	Distinctive	3	Distinctive	3	Distinctive
Texture	2	Slightly Firm	3	Firm	4	Very Firm

Table 4 displays the result of the sensory attributes of the study in terms of aroma, color, taste and texture. In terms of aroma, it depicts the lesser gotu kola is mixed to the product, the less it perceives the odor of the gotu kola added to the pasta. In terms of color, it shows that the more amount of gotu kola added to the pasta, the nicer its color and appearance would be. On the other hand, in terms of taste, the more gotu kola added to the pasta, the more unique its taste would be. Lastly, in terms of texture, the more gotu kola added to the pasta, the more tender and “al dente” the pasta would be, if cooked.

Table 5 Level of liking of dried fettuccine pasta enriched with gotu kola

Sensory attributes	Treatment 1		Treatment 2		Treatment 3	
	WM	Description	WM	Description	WM	Description
Aroma	3.12	Like Moderately	3.15	Like Moderately	3.07	Like Moderately
Color	2.98	Like Moderately	3.20	Like Moderately	3.33	Like Very Much
Taste	2.86	Like Moderately	3.11	Like Moderately	3.39	Like Very Much
Texture	2.87	Like Moderately	3.25	Like Very Much	3.40	Like Very Much
AWM	2.96	Like Moderately	3.18	Like Moderately	3.30	Like Very Much

Table 5 reveals that treatment 3 got the highest average weighted mean of 3.30 which described as “like very much” in terms of aroma, color, taste and texture because of its gotu kola content (75g) compared to treatments 1 (25g) and 2 (50g).

Table 6 reveals the difference on the level of liking of the dried fettuccine pasta in three treatments. It shows that it had a significant difference since the computed f-value is greater than the tabular f-value. Therefore, it implies that the three treatments had different odor, shade, flavor and consistency because the three treatments have different measurement of gotu kola added to the ingredients of pasta. Thus, the null hypothesis is rejected.

Table 6 Difference on level of liking of dried fettuccine pasta in three treatments

Difference on the level of liking of the dried fettuccine pasta in three treatments	Computed f-value	Tabular f-value	Interpretation	Decision
	At 5% level of significance			
	41.16	3.03	Significant	Reject null hypothesis

Table 7 Post hoc analysis in difference on level of liking of the dried fettuccine pasta in three treatments

Post-Hoc Tukey HSD test			
Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
TR 1 v TR 2	6.7442	0.0010053	** p<0.01
TR 1 v TR 3	12.8251	0.0010053	** p<0.01
TR 2 v TR 3	6.0809	0.0010053	** p<0.01

Table 7 denotes that the pairs of treatments were significantly different from each other in the level of liking of the dried fettucine pasta in three treatments. Therefore, it implies that treatments 1, 2 and 3 have big difference in the respondents' level of liking since treatment 1 had 25 grams gotu kola, treatment 2 had 50 grams of gotu kola and treatment 3 had 75 grams of gotu kola.

CONCLUSION

Based on the result of the study, the nutritive value of the three treatments of Dried Fettucine Pasta Enriched with Gotu Kola: T1- 25 grams of fresh gotu kola, T2- 50 grams of fresh gotu kola, and T3- 75 grams of fresh gotu kola was evaluated by F.A.S.T Laboratories and found out that in every 100 grams of it is rich with nutrients and no preservatives added.

The dried fettucine pasta has a longer shelf life if kept in a room temperature than kept in a refrigerated temperature. The pasta should be completely dried to have a longer shelf life since the moisture content of the pasta can cause the product to spoil easily.

Based on statistical result in the level of likeness of Dried Fettucine Pasta Enriched with Gotu Kola shows that Treatment 3- Pasta with 75 grams of fresh Gotu Kola as rated "like very much" in terms of color, taste and texture. The result reveals that there was a significant difference in the level of liking of the dried fettucine pasta in three treatments, therefore it implies that all treatments had different odor, shade, flavor and consistency because the three treatments have different measurement of gotu kola added to the ingredients of pasta.

ACKNOWLEDGEMENTS

As the researcher journeyed throughout this study, many people helped and supported her along the way. It is only right to thank and give these people appreciation and recognition.

The researcher would like to express her heartfelt gratitude to the Almighty God for the blessings, guidance and grace; To Dr. Jean F. Nebrea, the co-author, for rendering her time, effort, and encouragement to continue undertaking the study, for sharing her knowledge and expertise for going over the paper; To Dr. Mary Grace C. Ramada, the editor, for her assistance and effort in correcting the grammar of this paper; To Prof. Edelmarie A. Cellan, the statistician, for her pieces of advice in the computation of statistical treatment and providing the correct formula; To 13th ICERD Organizing Committee, for granting my request to be one of the presenters for the 13th International Conference on Environmental and Rural Development; To Research Development and Extension Committee of BISU, for the assistance, giving support especially in processing my prepayment, and for providing funds; To Bohol Island State University, for the opportunity you had given me to be one of the presenters for the 13th International Conference on Environmental and Rural Development; To College of Technology and Allied Sciences- Research Development Office, for the trust you had given me to be selected as one of the faculty researchers; and To the Respondents, Food Technology Experts and Consumers, for the time in answering the questionnaires as and who helped the researcher in the collection of the data.

REFERENCES

- Alfaro, D. 2022. What is fettuccine? A guide to buying, cooking and storing fettuccine. The Spruce Eats, Retrieved from <https://www.thespruceeats.com/what-is-fettuccine-995667>
- American Botanical Council. 2008. Gotu kola, Medical and spiritual uses. American Botanical Council, Retrieved from <http://herbalgram.org/resources/herbclip/herbclip-news/2008/gotu-kola-medical-and-spiritual-uses/>
- Christensen, E. 2019. Dry pasta vs. fresh pasta, What's the difference? Kitchn is, Retrieved from <https://www.thekitchn.com/dry-pasta-vs-fresh-pasta-whats-47888>
- Congress of the Philippines Republic of the Philippines. 2009. Food and drug administration act of 2009. Republic Act No. 9711, Philippines, Retrieved from <https://www.officialgazette.gov.ph/2009/08/18/republic-act-no-9711/>

- Das, A.J. 2011. Review on nutritional medicinal and pharmacological properties of *Centella asiatica* (Indian pennywort). *Journal of Biologically Active Products from Nature*, 1 (4), 216-228, Retrieved from https://www.researchgate.net/publication/260041417_Review_on_Nutritional_Medicinal_and_Pharmacological_Properties_of_Centella_asiatica_Indian_pennywort
- Forever Healthy and Young. 1990. Gotu Kola, Two leaves a day keep old age away, Retrieved from <http://foreverhealthy.blogspot.com/2012/04/gotu-kola-two-leaves-day-keep-old-age.html>
- Harris, S. 2018. Is pasta good or bad for you? *Medical News Today*, Retrieved from <https://www.medicalnewstoday.com/articles/322564#whole-grain-vs-white>
- Icahn School of Medicine at Mount Sinai. 2018. Gotu kola. Mount Sinai, Retrieved from <https://www.mountsinai.org/health-library/herb/gotu-kola>
- Krieger, E. 2017. Herbal health benefits. *Herb Essentials*, Retrieved from <https://www.hiclassblends.com/2017/01/herbal-health-benefits/>
- Light, P.D. 2011. What is herbalism? *Appalachian Center for Natural Health*, Retrieved from <https://www.phyllisdlight.com>
- Stuart, G.U. Jr. 2018. Takip-kohol, *Centella asiatica* (L.) Urb. *Philippine Medicinal Plants*, Retrieved from <http://www.stuartxchange.org/TakipKohol.html>
- Wikimedia. 2022. Department of science and technology (Philippines). *Wikimedia Foundation*, Retrieved from [https://en.wikipedia.org/wiki/Department_of_Science_and_Technology_\(Philippines\)](https://en.wikipedia.org/wiki/Department_of_Science_and_Technology_(Philippines))



Proposal of New Pickles to Improve Food Sanitation at Wet Markets in Cambodia

SOKLY SORM

Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

YOSHIKI MURAMATSU*

Tokyo University of Agriculture, Tokyo, Japan

Email: y-murama@nodai.ac.jp

DAIKI OKA

Tokyo University of Agriculture, Tokyo, Japan

YURI TANIOKA

Tokyo University of Agriculture, Tokyo, Japan

MASATAKA UCHINO

Tokyo University of Agriculture, Tokyo, Japan

SHUKI MURAMATSU

Showa Women's University, Tokyo, Japan

MOTOE SEKIDO

Yamanashi Gakuin Junior College, Yamanashi, Japan

TAKAHIKO NAKAMURA

Tokyo University of Agriculture, Tokyo, Japan

TORU NAKAJIMA

Tokyo University of Agriculture, Tokyo, Japan

EIICHIRO SAKAGUCHI

Tokyo University of Agriculture, Tokyo, Japan

SHOTARO KAWAKAMI

Tokyo University of Agriculture, Tokyo, Japan

MARI ARIMITSU

Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan

MACHITO MIHARA

Tokyo University of Agriculture, Tokyo, Japan

Received 20 January 2022 Accepted 13 June 2022 (*Corresponding Author)

Abstract The lack of heat treatment is one possible factor leading to highly contaminated pickles with microbes, including the bacteria that cause food poisoning. A heating process that sterilizes food products is effective in reducing the microbial content of pickles. We applied heat treatments to ensure that homemade pickles were safe to consume. In this study, 2 kinds of pickled young papaya were made to develop a new, safe processed food that effectively utilizes agricultural products. The objective was to evaluate the possibility of acceptance of these samples in Cambodia and other Asian countries. The sensory evaluation indicated that the samples were acceptable but still need further improvement.

Keywords young papaya, pickle, heat treatment, sensory evaluation, acceptability

INTRODUCTION

Pickles are a popular ready-to-eat food, and most pickles are produced in traditional ways in Cambodia. Pickles are easy to make, and do not require for any special equipment or skills. The basic procedure for making pickles is to wash the vegetables and then add sugar, salt, and other ingredients such as fish sauce, soy sauce, garlic, chili, and rice. Most pickles are stored in jars and placed in the sun or in a room at ambient temperature for 1 to 4 days. Pickles are commonly sold in wet markets in Cambodia. Almost all pickles sold in the wet markets are made without any heating process. Furthermore, the pickled product is displayed in a wet market under poor storage conditions; for example, there is no temperature control and no packaging. The hygiene practices of the local wet markets are very poor, which has subsequently led to food contamination. This situation is risky, and food poisoning incidents are often associated with these pickled products (Anal et al., 2019). Chrun et al. (2017) also pointed out the poor hygiene at the local wet markets in Cambodia and the necessity of identifying the source of contamination. According to reports by Muramatsu et al. (2020a, 2020b), the pickles sold at the wet markets in Cambodia are highly contaminated with microbes, including bacteria that cause food poisoning. In addition, the inspection of wet markets showed that the pickle products were not handled in a hygienic manner. It is necessary for food handlers to receive practical knowledge on food hygiene to prevent the spread of bacterial food contamination. This contamination could be caused by a manufacturing process that does not use heat treatment. Pasteurization destroys pathogenic microorganisms in certain foods and beverages. A new pickling method that adds heat treatment to the production process is needed to reduce the risk of food poisoning posted by pickled products. Adding a pasteurization procedure to the production process can improve food safety and/or food sanitation (Breidt et al., 2004). A heating process that pasteurizes foods to reduce food spoilage microbes can be applied to many kinds of food products.

We conducted a survey of Cambodians in their twenties and thirties regarding pickles via the Messenger App and received 30 responses. Some respondents mentioned that they enjoy eating pickles on a daily basis but that consuming pickles causes them to vomit, experience diarrhea and bloat, and have headaches. The majority of respondents suggested that pickles should be made in a safe and high-quality manner, including packaging. The necessity of improving and guaranteeing food sanitation and safety were also recognized in this survey.

In Cambodia, papaya is an important agricultural product and an existing resource that is easy to grow and maintain. People can grow papaya in their homes or on a large scale in all areas of the country. People grow papaya as their livelihood, they consume it, and they sell it fresh in wet market (MAFF/GDA, 2010). Papaya can be harvested and is available year-round. A small amount of mature papaya (which is light yellow in color) is often pickled, but young fresh papaya is not pickled. Young fresh papaya or young papaya is unripe papaya before it ripens to yellow. Young papaya is also called "green papaya". The colors of the pericarp and the flesh of fruit of young papaya are green and white, respectively.

In this study, 2 kinds of pickled young papaya were developed to test a new, safe, processed food. These pickles are kinds of quick pickles and are not fermented pickles. This study aimed to find the new usage of young papaya to develop microbiologically safe pickles. We examined the possibility of acceptance of these samples in Cambodian and Asian markets. Heat treatment was added to the production process. The pickles were packed in a glass bottle, which is easy to pasteurize and enhances product value, quality, and safety. Glass bottles are readily accessible in Cambodia at a reasonable price and can be reused. Fresh young papayas are also reasonably priced and easy to find in Cambodia.

OBJECTIVE

The objectives of this study were 1) to develop pickled young papaya processed with heat

treatment and 2) to evaluate the possibility of acceptance of the pickles that ensure food sanitation in Cambodian and Asian markets.

METHODOLOGY

Materials and Pickle Production Process

Young papaya (*Carica papaya*) imported from Thailand were purchased at a supermarket in Tokyo, Japan. Before testing, the young papayas were stored in a refrigerator at approximately 4°C.

To develop the composition of seasoning, we first processed 3 kinds of pickles based on a book of Japanese recipes and Cambodian homemade recipes. These pickles were evaluated by 8 Cambodians in Phnom Penh, Cambodia. Based on the evaluation results and comments from the panelists, we revised and decided on 2 types of seasoning: sour pickles and salty pickles. Table 1 shows the seasonings used to make the 2 types of pickled young papayas. The green pepper in Table 1 was a fresh green pepper (*Piper nigrum*). The compositions of the pickles processed in this study are presented in Table 2.

Table 1 Seasonings used to make the 2 types of samples

Seasoning	Sample	
	Sour	Salty
Sugar (g)	115	110
Salt (g)	12	25
Vinegar (ml)	300	190
Water (ml)	200	190
Soy sauce (ml)	-	11
Fish sauce (ml)	-	59
Green pepper (piece)	20	-
Chili (piece)	-	1

*6-8 pieces of young papaya (about 30-40 cm³)

Table 2 Compositions of the 2 types of pickled young papayas

Component (%)	Sample	
	Sour taste	Salty taste
Moisture	81.2	73.5
Protein	0.6	1.4
fat	0	0
Ash	1.4	5.0
Carbohydrates	16.8	20.1
(Sugar)	(13.6)	(17.2)
(Dietary fiber)	(3.2)	(2.9)
Salt equivalent	1.1	4.6

Fig. 1 shows the production process for the 2 types of pickles. After the peel was removed from the young papaya, it was cut into a rectangular parallelepiped (10 mm in depth and width, and 50 mm in height) using a knife. The liquid seasoning was heated to boiling, and the spice and 6-8 pieces of young papaya were placed into a glass bottle up to 3-5 mm from the bottle lid. After closing the lid of the bottle (sealing), the bottle was turned upside down. The hot glass bottle filled with seasoning and young papaya was submerged in hot water at a temperature of 70°C. The hot water was heated to boiling. After coming to a boil, the glass bottle was maintained in boiling water for 10 minutes to raise the center temperature above 75°C. After this pasteurization, the glass bottle was cooled at room temperature (approximately 25°C) in the inverted state. The pasteurization conditions and methods adopted in this study conformed to the regulations for enforcement of the food sanitation act in Japan. The pickles were then stored at room temperature for 4 days. The pH values of the liquid seasonings were 3.60 for the sour pickles and 3.35 for the

salty pickles. Fig. 2 shows photographs of the sour and salty samples. The appearances of the sour and salty samples were light and dark yellow, respectively. The heating treatments, i.e., the heating of the liquid seasoning, the hot packing, and the pasteurization were important additions to the production process to improve and/or maintain food sanitation.

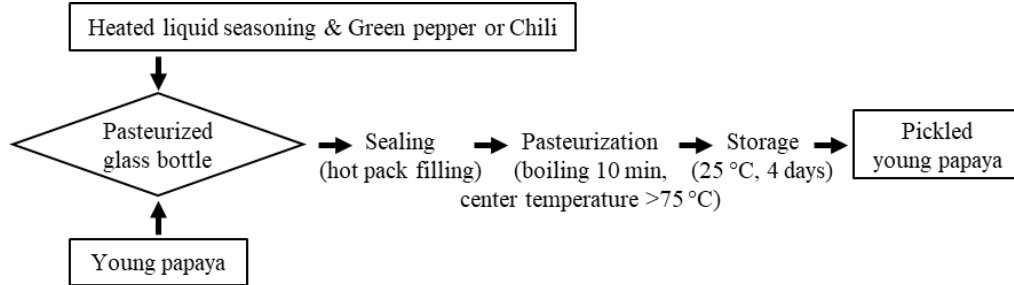


Fig. 1 Production process for the 2 types of pickled young papayas: sour and salty



Fig. 2 The appearance of sour and salty pickles

Sensory Evaluation of Pickled Young Papaya

The color, sweetness, sourness, saltiness, flavor, texture, and overall evaluation of each sample were quantified using a five-point hedonic scale (1: strongly dislike, 2: dislike, 3: neutral, 4: like, and 5: strongly like) for the sensory test (preference type). The sensory evaluations were conducted in Japan (Setagaya) and in Cambodia (Phnom Penh). Table 3 presents the panelist demographics. The total number of panelists was 32, and the nationality of all panelists was Asian. The panelists “Cambodia-1” evaluated only the sour sample in Cambodia; otherwise, the panelists evaluated both samples in Japan. The panelists were divided into 2 panels: Cambodian and non-Cambodian for the statistical analysis of the sensory evaluation results. The sour and salty samples were tested by 15 Cambodian panelists and 17 non-Cambodian panelists (total, 32 panelists) and 7 Cambodian panelists and 17 non-Cambodian panelists (total, 24 panelists), respectively.

Table 3 Panelist demographics for the sensory evaluation of the samples

Nationality	Number	Age (Average)
Cambodia-1 ^a	8	21-35 (28)
Cambodia-2 ^b	7	23-38 (27)
Vietnam ^b	5	20-24 (22)
Thailand ^b	4	23-38 (29)
Myanmar ^b	3	22-25 (24)
Philippines ^b	2	29, 30
Indonesia ^b	2	24, 36
Sri Lanka ^b	1	26

a: These panelists evaluated only the sour taste sample in Cambodia.

b: These panelists evaluated both samples in Japan.

RESULTS AND DISCUSSION

Fig. 3(a) shows the sensory evaluation results for the sour sample. The results for the Cambodian panel in Fig. 3(a) include the panelists “Cambodia-1” and “Cambodia-2” shown in Table 3. The average scores of the sensory evaluation characteristics of the sour sample ranged from 3.3-3.7 for Cambodians and 3.6-3.9 for non-Cambodians. The overall evaluation shows whether the pickled product was judged overall to be acceptable or not acceptable. The average overall evaluation was scored 3.5 by Cambodians and 3.9 by the non-Cambodian panelists. The non-Cambodian panel gave higher scores than the Cambodian panel, and the sour sample was more preferred by non-Cambodians than by Cambodians. The average values of each evaluation characteristic for the sour sample were tested for differences (t test) between the Cambodian and the non-Cambodian panels, and there were no significant differences (at the 5% significance level) for any characteristics, except for the overall evaluation. The overall evaluation score of the non-Cambodian panel was significantly higher, and this result showed the high acceptability of the sour sample by the non-Cambodian panel. These results indicate that the sour sample was acceptable by Cambodians and other Asians because the overall evaluation scores for both panels were over 3.0. In addition, the t test for each characteristic and for the average value between the panelists of "Cambodia-1" and "Cambodia-2" (Table 3) showed no significant differences. This result suggests that the evaluation results obtained in Japan could be applied to evaluate the acceptability of the samples in Cambodia.

Most panelists evaluated the texture as adequate but not firm. Some Cambodian panelists commented that the sweetness was adequate, and if the sourness and saltiness were reduced slightly in the sour sample, the evaluation of this sample would increase. In contrast, some non-Cambodian panelists stated that the sourness was adequate, and increasing the sweetness and saltiness slightly might improve the score.

The sensory evaluation of the salty sample is presented in Fig. 3(b). The average scores for the salty sample were 2.6-3.9 for Cambodians and 2.9-4.3 for non-Cambodians. The t test showed no significant differences in the average values for each characteristic between the Cambodian and the non-Cambodian panels. Except for the texture, the non-Cambodian panelists assigned higher scores than the Cambodian panelists on all characteristics. The average values for color were nearly 4.0, and the color of the salty sample was favored by both panels. Although the average values of saltiness for the Cambodian and the non-Cambodian panels and sweetness for the Cambodian panel did not exceed 3.0, the overall evaluation scores were 3.1 for the Cambodian panel and 3.4 for the non-Cambodian panel.

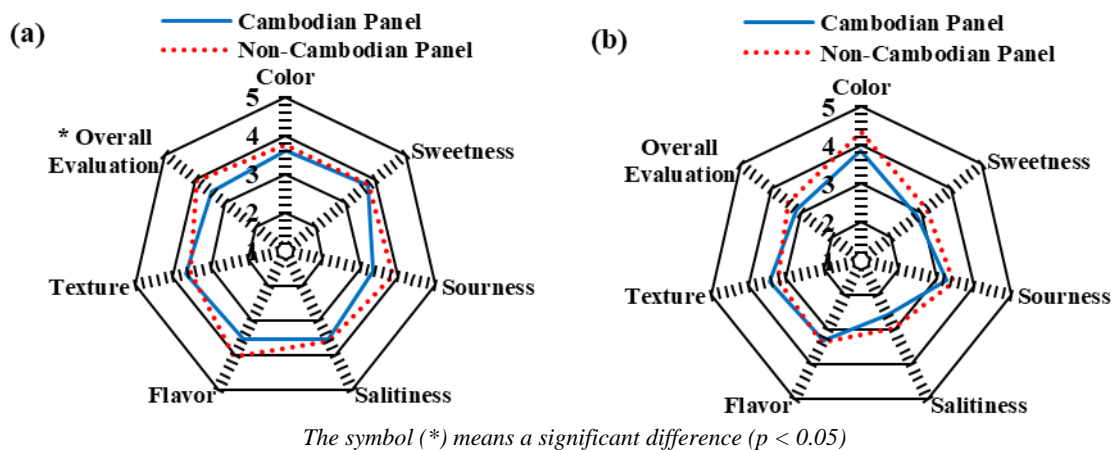


Fig. 3 Comparison of sensory evaluation of pickled young papaya between Cambodian and non-Cambodian panels (a) sour sample; (b) salty samples

The panelists commented that the dark yellow color of the salty sample was attractive and looked delicious, but the texture was soft, and a crunchier texture might change the evaluation. Most Cambodian panelists indicated that the taste of the salty sample was salty and lacked

sweetness. Although there are opportunities for improvement regarding the taste and the texture of the salty sample, i.e., lowering the salt content, increasing the sweetness, and increasing the crunchiness, the acceptability of the salty sample was indicated by the overall evaluation scores (over 3.0).

To improve food sanitation, heat treatments were added to the production process of the sour and salty samples. These samples received mostly favorable evaluations from Cambodian and Asian panelists. The heat treatments and the preservation period also affected the texture of the pickles. Therefore, it would be useful to investigate the relationships between these factors. Further studies will require more panelists to analyze the evaluation of pickles in detail and to assess their acceptability. We will optimize the process to produce safe, high quality, and more acceptable pickles.

CONCLUSION

Young papaya was used to develop a new pickle product in this study. The heat treatments, i.e., the heating of liquid seasoning, a hot pack, and pasteurization were added to the production process to improve and guarantee food safety. Two types of young papaya pickles, the sour and salty, were made and evaluated by Cambodians and Asians in Cambodia and Japan. The color, sweetness, sourness, saltiness, flavor, texture, and overall evaluation of each sample were quantified using a five-point hedonic scale (1: strongly dislike, 2: dislike, 3: neutral, 4: like, and 5: strongly like) for the sensory test (preference type). The sensory evaluation indicated that the samples were considered to be acceptable but needed further improvement. Because both pickles received mostly favorable evaluations from Cambodian and Asian panelists based on the overall evaluation scores (over 3.0), both pickles were potentially acceptable as new processed foods in Cambodia and in other Asian countries. This finding will be useful for food preservation, reducing postharvest losses, providing jobs for domestic Khmer people (particularly women), and increasing the income of citizens as well as the Cambodian nation.

REFERENCES

- Anal, A.K., Perpetuini, G., Petchkongkaew, A., Tan, R., Avallone, S., Tofalo, R., Nguyen, H.V., Chu-Ky, S., Ho, P.H., Phan, T.T. and Wache, Y. 2020. Food safety risks in traditional fermented food from South-East Asia. *Food Control*, 109, 1-9, Retrieved from DOI <https://doi.org/10.1016/j.foodcont.2019.106922>
- Breidt, J.F., Hayes, J.S. and McFeeters, R.F. 2004. Independent effects of acetic acid and pH on survival of *Escherichia coli* in simulated acidified pickle products. *Journal of Food Protection*, 67 (1), 12-18, Retrieved from DOI <https://doi.org/10.4315/0362-028X-67.1.12>
- Chrun, R., Hosotani, Y., Kawasaki, S. and Inatsu, Y. 2017. Microbiological hazard contamination in fermented vegetables sold in local markets in Cambodia. *Biocontrol Science*, 22 (3), 181-185, Retrieved from DOI <https://doi.org/10.4265/bio.22.181>
- General Directorate of Agriculture, Ministry of Agriculture, Forestry and Fisheries (GDA, MAFF). 2010. Technical book of crops in Cambodia. GDA of MAFF, Cambodia, Retrieved from <http://www.maff.gov.kh>
- Muramatsu, S., Uchino, M., Sorm, S., Tanikoka, Y., Oka, D., Muramatsu, Y., Nakajima, T., Sekido, M., Nakamura, T., Chay, C. and Mihara, M. 2020. Evaluation of bacterial contamination levels in pickles sold at wet market in Cambodia, Part 2, Detection of several food-poisoning bacteria of 48 samples from Phnom Penh. *International Journal of Environmental and Rural Development*, 11 (1), 121-126, Retrieved from DOI https://doi.org/10.32115/ijerd.11.1_121
- Muramatsu, S., Uchino, M., Tanikoka, Y., Sorm, S., Oka, D., Muramatsu, Y., Nakajima, T., Sekido, M., Nakamura, T., Chay, C. and Mihara, M. 2020. Evaluation of bacterial contamination levels in pickles sold at wet market in Cambodia, Part 1, In case of samples from Kampong Cham and Phnom Penh. *International Journal of Environmental and Rural Development*, 11 (1), 115-120, Retrieved from DOI https://doi.org/10.32115/ijerd.11.1_115



Cadmium Bioaccumulation in *Amaranthus spinosus* L. Grown in Contaminated Soil of Benguet Province, Philippines

ELIZABETH T. DOM-OGEN*

Benguet State University, La Trinidad, Benguet, Philippines
Email: e.dom-ogen@bsu.edu.ph

ROMEO A. GOMEZ, JR.

Benguet State University, La Trinidad, Benguet, Philippines

Received 3 February 2022 Accepted 13 June 2022 (*Corresponding Author)

Abstract Phytoremediation has become an alternative technology for cleaning up contaminated areas by accumulation in the root and shoot systems. The study conducted a 98-day pot experiment to determine Cd accumulation and its morphological and physiological effects on *Amaranthus spinosus* L. grown in the non contaminated forest (S1) and mine contaminated (S2) soils of Benguet. Soil and plant tissue analysis were done using AAS method; quantitative descriptive method for morphological analysis; titration method for vitamin C analysis; and Kjeldahl method for protein analysis. *Amaranthus spinosus* L. grown in S1 accumulated 0.52 mg/kg Cd in the root and 0.88 mg/kg Cd in the shoot with soil Cd concentration of 3.70 mg/kg at 7.43 pH. In S2, *A. spinosus* L. had taken up 0.000012 mg/kg Cd in the roots and in the shoot systems with 0.90 mg/kg Cd soil concentration at 4.19 pH. Biological Accumulation Coefficient (BAC = 0.24) was generally weak since the equivalent is less than 1 (BAC < 1, 0.24) while translocation factor (TF = 1.69) is greater than 1 (TF > 1, 1.69). For morphological characteristics comparing S1 and S2 results are the following: root length (372.33 mm and 284.70 mm); shoot length (399.33 mm and 132.33 mm); and, biomass (22.53 grams and 9.27 grams). Highly significant differences were also noted for S1 and S2 on root length, shoot length, and biomass at $\alpha = 0.01$ with p – values of 0.002, 0.000, and 0.002, respectively. For the vitamin C and protein content, both (S1 and S2) were not affected. From these results, it can be concluded that *Amaranthus spinosus* L. can accumulate significant concentration of Cd in its root and shoot systems and allows Cd mobility in its system. It is then recommended that the capability of *Amaranthus spinosus* L. for Cd tolerance requires further studies.

Keywords *Amaranthus spinosus* L., bioaccumulation, phytoremediation, physiological, morphological characteristics

INTRODUCTION

Environmental sustainability issues are pressuring global concerns at present because of increasing population and industrialization. It had been realized that anthropogenic activities such as mining despite its substantial contribution to economic growth and development resulted towards environmental problems (Castillo et al., 2010). In the Philippines, it had established mining industries but problems with proper tailings disposal and policies for mitigation are not yet in place causing leakage of hazardous chemicals like cadmium, lead and copper (CPA, 2007). The presence of such contaminants in excess can lead to the reduction and inhibition of growth in plants inflicting serious morphological, metabolic, and physiological anomalies. Correspondingly, these contaminants cannot be mineralized or degraded to less toxic forms; can be leached to nearby farmlands and accumulated through the food chain; thus, requiring suitable methods for their elimination (Chen et al., 2014).

Addressing these, phytoremediation has become an alternative technology for cleaning up contaminated areas. *Amaranthus spinosus* L. (Amaranthaceae) commonly called pigweed can bioconcentrate Cd, Zn and Fe invariably high in leaf tissues (Prasad and Freitas, 2003), and shows best morphological and anatomical structure adaptation to stressful environments (Gharge and Menon, 2017).

Correspondingly, *Amaranthus spinosus* L. is a potential agent for heavy metal accumulation and translocation for Cu, Pb and Cd (Chinmayee et al., 2012) and among the dominant species growing in some mine sites in the Philippines (Malik et al., 2010).

OBJECTIVE

The study concerns the investigation of the potential ability of *Amaranthus spinosus* L. to accumulate Cd in the root and shoot system and how it responds morphologically and physiologically.

METHODOLOGY

Sample Sites

The soil sampling sites were located at Alno, La Trinidad and Antamok, Itogon, Benguet (Fig. 1). La Trinidad and Itogon are two of the 13 municipalities that comprise Benguet which, together with five other provinces, make up the Cordillera Administrative Region. Alno has an estimated land area of 958.35 ha. It is the third largest village in this municipality of La Trinidad. An area of 30.8 ha of forest and brushlands is classified as the Alno communal forest (Lumbres et al., 2014). The municipality of Itogon is the core of the Baguio Mining District. Before the World War II, large-scale mines operated, small-scale mining thrived. For Antamok, Itogon decommissioned tailings dam had been abandoned for 22 years during the collection but still a basin of mine waste for small scale miners since the tailing dam used for the study had operated for 7 years and was shut down last April 1998 (Chaloping-March, 2019).

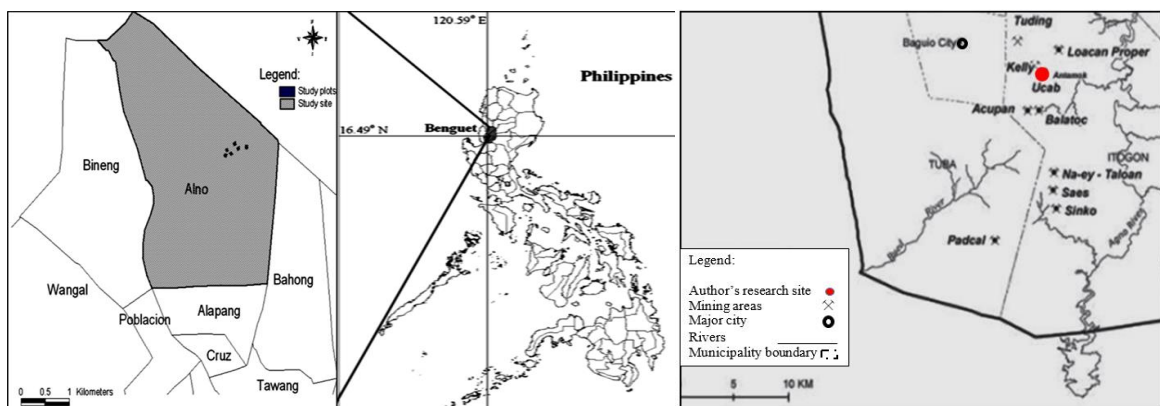


Fig. 1 Location map of Alno, La Trinidad, Benguet and of Antamok, Itogon, Benguet

Soil Sample Characteristic, pH and Cadmium Analysis

The identification of non-contaminated and contaminated soil was based on Pfeiffer et al. (1988) and the US EPA (1994) for standard maximum concentration of contaminants for toxicity characteristics. Soil samples were collected using composite soil sampling (Brady and Weil, 2000). For soil pH determination the potentiometric method was employed. The concentrations of heavy metals in soil samples were determined using Atomic Absorption Spectroscopy (AAS).

Plant Morphological Observation on the 98th Day

Plants were carefully uprooted from the plastic pots then washed properly. The plants were cut separating the root and shoot system for length measurement, and were air dried. Also, it was oven dried at 60 degrees Centigrade for biomass.

Determination of Vitamin C and Protein Content of the Plant on the 98th Day

The plants used in the morphological study were processed and analyzed separately. The vitamin C content from the plant samples was measured based on the redox titration. The total protein content from the plant samples was measured based on the Kjeldahl method.

Bioaccumulation Evaluation

Bioaccumulation and phytoextraction were evaluated in terms of Biological Accumulation Coefficient (BAC), Biological Coefficient Factor (BCF) and Trans-location Factor (TF) whereby;

$$BAC = [\text{metal}] \text{ shoot} / [\text{metal}] \text{ soil}$$

$$BCF = [\text{metal}] \text{ root and shoot} / [\text{metal}] \text{ soil}$$

$$TF = [\text{metal}] \text{ shoot} / [\text{metal}] \text{ root}$$

Treatment of Data

The data were tabulated, interpreted, and analyzed using comparative experimental research design. The t-test was used to determine the differences in the soil pH and soil Cd content of non-contaminated and contaminated soil; plant tissue Cd content analysis of each plant systems (root and shoot); and the plant morphological and physiological changes in *Amaranthus spinosus* L. on the 98th day.

RESULTS AND DISCUSSION

Cadmium Bioaccumulation in the Root and Shoot System of *Amaranthus spinosus* Linn

Table 1 shows the mean Cd concentration in the root and shoot systems of *Amaranthus spinosus* L. planted on non-contaminated (S1) and contaminated (S2) soils. The mean Cd content for the S1 in the root and shoot systems was non-detectable as represented by the value of 0.000012 mg/kg dry weight while for S2 in the root and shoot systems were 0.520000 and 0.880000 mg/kg dry weight, respectively.

Table 1 Mean cadmium concentration on the root and shoot of *Amaranthus spinosus* L.

Plant organs	Non-contaminated soil (S1) mean (mg/kg)	Contaminated soil (S2) mean (mg/kg)	P - value
Root	0.000012	0.520000	0.002**
Shoot	0.000012	0.880000	0.003**

Legend:** highly significant at $\alpha = 0.01$

Using t- test at $\alpha = 0.01$, the accumulation of cadmium in the root and shoot systems of *A. spinosus* L. comparing S1 and S2 is highly significant with a p = value of 0.002 and 0.003, respectively. This suggests that with 0.90 mg/kg in S1 mean Cd concentration, absorption and accumulation from the soil to the roots and translocation to the shoot system did not occur while at 3.70 mg/kg mean Cd concentration in S2 allows to some limited extent of Cd absorption and accumulation by the root from the soil then translocated to the shoot system.

According to Pantazis et al. (2007), the uptake of Cd by root from the soil depends on the soil properties like Cd concentration and level of organic matter aside from pH. Dada (2019) reported that *A. spinosus* L. accumulated 5.24 mg/kg in the root and 3.03 mg/kg in the shoot in soil of pH of 8.4 and 16.10 mg/kg soil Cd concentration. Moreover, Carrion and Mendoza (2019) result shows that *A. spinosus* L. accumulated 0.55 mg/kg Cd in the shoot system with 7.49 soil pH and 2.02 mg/kg Cd soil concentration.

Bioaccumulation Evaluation of *Amaranthus spinosus* L.

Bioaccumulation evaluation of *Amaranthus spinosus* L. were based from the computed value of Biological Accumulation Coefficient (BAC), Biological Coefficient Factor (BCF) and Translocation Factor (TF). The BAC value is 0.24, BCF is 0.14 and TF value is 1.69. The BAC (0.24) and BCF (0.38) values were generally weak in *A. spinosus* L. (Table 2) since their equivalents are less than 1 (BAC & BCF < 1) while Translocation Factor (TF) is greater than 1 (TF > 1 = 1.69). The TF value (TF > 1) indicates capability to accumulate and transport cadmium in its organs at 3.70 mg/kg soil Cd concentration and 7.43 soil pH. With the value of 1.69 TF_{Cd}, it could be deduced that the translocation of Cd from the roots to the shoot system of *Amaranthus spinosus* L. was relatively efficient but it cannot be identified as an excluder, accumulator or extractor.

Table 2 BAC; TF; and BCF of *Amaranthus spinosus* L.

Accumulation characteristics	Equivalent
BAC	0.24
TF	1.69
BCF	0.38

Cadmium Bioaccumulation Effect on Morphological Characteristics of *Amaranthus spinosus* L.

The morphological characteristics of *Amaranthus spinosus* L. measured after 98 days of growth are summarized in Table 3. These characteristics, with the paired mean measurements obtained from those planted in S1 and S2 soils respectively, include: root length (372.33 mm and 284.70 mm); shoot length (399.33 mm and 132.33 mm); and, biomass (22.53 grams and 9.27 grams).

Table 3 Morphological characteristics of the *Amaranthus spinosus* L. on the two sites

Characteristics	Non-contaminated soil (s1) mean	Contaminated soil (s2) mean	P - value
Root length (mm)	372.33	284.70	0.002**
Shoot length (mm)	399.33	132.33	0.000**
Biomass (grams)	22.53	9.27	0.002**

Legend: ** highly significant at $\alpha = 0.01$

Highly significant differences were noted for S1 and S2 on root length, shoot length, and biomass at $\alpha = 0.01$ with p – values of 0.002, 0.000, and 0.002, respectively. *Amaranthus spinosus* L. planted at 0.90 mg/kg in S1 are longer in root and shoot length and had higher biomass as compared to *Amaranthus spinosus* L. at 3.70 mg/kg soil concentration of S2; the latter had short root and shoot length and had less biomass.

The morphological results of *Amaranthus spinosus* L. in S1 having longer root and shoot length and higher biomass as compared to S2 having short root and shoot length and less biomass can be due to the nil and greater amounts of Cd root and shoot accumulation after the 98-day growth, respectively. Other observations for S2 that are not found in S1 were thicker stem diameter, delayed development, and leaf chlorosis.

These morphological observations in S2 are the results of plants ability to adjust to its contaminated environment by delaying or arresting mitotic division (Baran et al., 2010) affecting the length development of the root. The short roots will be deprived of nutrient demand and supply because its source is limited only to its immediate surroundings resulting to short shoot system because of plant nutrient deficiency. Moreover, the presence of Cd in the plant system inhibits photosynthesis hampering growth and development resulting to plant decreased biomass (He et al., 2015).

Effect on the Vitamin C and Protein Content of *Amaranthus spinosus* L.

The vitamin C content in organs of *Amaranthus spinosus* L. planted in both S1 and S2 soils is 2.40%. The plant protein content, on the other hand, is at 5.18% (S1) and 4.73% (S2). Statistically, there were no significant differences in the vitamin C (2.40% at 0.90 mg/kg – S1 and 2.40% at 3.70 mg/kg – S2) and protein (5.18% at 0.90 mg/kg – S1 and 4.73% at 3.70 mg/kg – S2) contents of *Amaranthus spinosus* L. in both soil samples were noted. This is supported by the p-values obtained comparing S1 and S2 for the physiological characteristics at 1.000 and 0.684 respectively (Table 4). The highly significant differences of the soil Cd concentrations of S1 and S2 apparently did not at all affect the vitamin C and protein contents of plants grown in both S1 and S2. The result may be due to the plants ability to maintain its metabolic activities by storing Cd in the cell wall and vacuole of the root and the shoot systems, thereby continuing growth and development.

Table 4 Mean vitamin C and protein content of the *Amaranthus spinosus* L. plant organs on the two sample sites

Physiological characteristics	Mean (%)		P - value
	Non-contaminated soil (s1)	Contaminated soil (s2)	
Vitamin C content	2.40	2.40	1.000 ^{ns}
Protein content	5.18	4.73	0.684 ^{ns}

Legend: ns - not significant at $\alpha = 0.01$

Vitamin C and protein are important factors for growth and development since protein responds to a wide variety of stresses within the plant body while vitamin C plays an important role in the adaptation and ultimate survival of plants (Dinakar et al., 2008). The result of the study was similar to the study of Jibril et al. (2017) on lettuce where soil Cd concentrations of 0, 3, 6, 9 and 12 mg/kg have no significant effect in flavonoids, vitamin C and proline. This was confirmed by Wang et al. (2009) on Cd toxicity on N metabolism in leaves of *Solanum nigrum* in 6.5 soil pH where the concentration did not decrease significantly in soil Cd concentration at 6, 12 and 24 mg/kg.

CONCLUSION

Phytoremediation is a low cost and environmental friendly method to eliminate soil contaminants. *Amaranthus spinosus* L. had been used since literatures suggest that it has the capability to extract heavy metals and can survive to adverse conditions. The findings of the study shows that there is a significant accumulation of Cd in *Amaranthus spinosus* L. on contaminated soil (root-0.52 mg/kg and shoot-0.88mg/kg) and non-detectable Cd accumulation in non-contaminated soil. *Amaranthus spinosus* L. plants in non-contaminated soil are taller compared to those in contaminated soils which are short. Given the morphological characteristics of the plants, it follows that those in S1 have higher biomass as those in S2 having lower biomass. Also, vitamin C and protein content are not affected by the amount of Cd in two sample sites. Therefore, *Amaranthus spinosus* L. can survive in the environment with 3.70 mg/kg soil Cd concentration at 4.19 pH.

REFERENCES

- Baral, M., Ankur, D., Chakraborty, S. and Chakraborty, P. 2011. Pharmacognostic studies on stem and leaves of *Amaranthus spinosus* Linn. International Journal of Applied Biology and Pharmaceutical Technology, 2 (1), 41-47.
- Brady, N.C. and Weil, R.R. 1990. The nature and properties of soil (14th ed.). Pearson, ISBN 978-0133254488, Boston, USA.
- Castillo, J.P., Verdu, M. and Valiente-Banuet, A. 2010. Neighborhood phylodiversity affects plant performance. Ecology, 91 (12), 3656-3663, Retrieved from DOI <https://doi.org/10.1890/10-0720.1>
- Chaloping-March, M. 2019. Antamok, Launchpad of industrial mining in the Philippines. In Chaloping-March, M. (Ed.), Social Terrains of Mine Closure in the Philippines, 80-99, Routledge, London, UK.
- Chen, L., Lon, S., Li, X., Won, Y., Chen, J. and Lui, C. 2014. Interaction of Cd-hyperaccumulator *Solanum nigrum* L. and functional endophyte *Pseudomonas* sp. Lk9 on soil heavy metals uptake. Soil Biology and Biochemistry, 68, 300-308, Retrieved from DOI <https://doi.org/10.1016/j.soilbio.2013.10.021>
- Chinmayee, M.D., Masesh, B., Pradesh, S., Mini, I. and Swapna, T.S. 2012. The assessment of phytoremediation potential of invasive weed *Amaranthus spinosus* L.. Applied Biochemistry and Biotechnology, 167 (6), 1550-1559, Retrieved from DOI 10.1007/s12010-012-9657-0
- Cordillera Peoples Alliance (CPA). 2007. Case study on the impacts of mining and dams on the environment and indigenous peoples in Benguet, Cordillera, Philippines. Retrieved from <https://www.studocu.com/ph/document/technological-university-of-the-philippines/engineering-economics/case-study-in-benguet-from-internet/11224770>
- Dada, O.E. 2019. Cadmium tolerance and phytoremediation strategies of selected tropical plants cultivated on industrial dump site under the influences of two mycobionts. West African Journal of Applied Ecology, 27 (2), 106-125, Retrieved from <https://www.ajol.info/index.php/wajae/article/view/192383>
- Dinakar, N., Nagajyothi, P.C., Suresh, S., Udaykiran, Y. and Damodharam, T. 2008. Phytotoxicity of cadmium on protein, proline and antioxidant enzyme activities in growing *Arachis hypogaea* L. seedlings. Journal of Environmental Science, 20 (2), 199-206, Retrieved from DOI [https://doi.org/10.1016/S1001-0742\(08\)60032-7](https://doi.org/10.1016/S1001-0742(08)60032-7)
- Gharge, S. and Menon, G. 2017. Morpho-anatomical adaptation in some herbs growing near Ulhas river polluted with industrial effluent. International Journal of Botany Studies, 2 (4), 43-48, Retrieved from <http://www.botanyjournals.com/archives/2017/vol2/issue4/2-4-18>
- He, S., He, Z., Yang, X., Stoffella, P.J. and Baligar, V.C. 2015. Soil biogeochemistry, Plant physiology and phytoremediation of cadmium-contaminated soils. In Sparks, D.L. (Ed.), Advances in Agronomy, 134, 135-225, Academic Press, Cambridge, USA.
- Jibril, S.A., Hassan, S.A., Ishak, C.F. and Wahab, P.E.M. 2017. Cadmium toxicity affects phytochemicals and nutrients elements composition of lettuce (*Lactuca sativa* L.). Hindawi Advance Agriculture, 1-7, Retrieved from DOI <https://doi.org/10.1155/2017/1236830>
- Lumbres, R.I.C., Palaganas, J.A., Micoso, S.C., Laruan, K.A., Besic, E.D., Yun, C.W. and Lee, Y.J. 2014. Floral diversity assessment in alno communal mixed forest in Benguet, Philippines. Landscape and Ecological Engineering, 10, 361-368, Retrieved from DOI <https://doi.org/10.1007/s11355-012-0204-5>
- Malik, R.N., Husain, S.Z. and Nazir, I. 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. Pakistan Journal of Botany, 42 (1), 291-301, Retrieved from [http://www.pakbs.org/pjbot/PDFs/42\(1\)/PJB42\(1\)291.pdf](http://www.pakbs.org/pjbot/PDFs/42(1)/PJB42(1)291.pdf)
- Pantazis, V., Kalavrouziotis, I. and Deligiannakis, I. 2007. Cu-Zn accumulation on soil plant system irrigated with wastewater. Proceedings in IWA Facing Sludge Diversities, Challenges, Risks and Opportunities. Antalya, Turkey, 673-680.
- Pfeiffer, E.M., Freytag, J., Scharpenseel, H.W., Miehlisch, G. and Vicente, V. 1988. Trace elements and heavy metals in soil and plants of the southeast asian metropolis Metro Manila and of some rice cultivation provinces in Luzon, Philippines. Hamburger Bodenkundliche Arbeiter, Band 11, Hamburg, Germany.
- Prasad, M.N.V. and De Oliveira Freitas, H.M. 2003. Metal hyperaccumulation in plants, Biodiversity prospecting for phytoremediation technology. Electronic Journal of Biotechnology, 6 (3), 285-321, Retrieved from <http://www.ejbiotechnology.info/index.php/ejbiotechnology/article/view/v6n3-6/617>
- U.S. Environmental Protection Agency (U.S. EPA). 1994. Test methods for evaluation of solid wastes, Physical, chemical methods (3rd Edition), Final Update 3A. CD ROM SW-846.
- Wang, H., Zhao, S.C., Liu, R.L., Zhou, W. and Jin, J.Y. 2009. Changes of photosynthetic activities of maize (*Zea mays* L.) seedlings in response to cadmium stress. Photosynthetica, 47 (2), 277-283, Retrieved from DOI <https://doi.org/10.1007/s11099-009-0043-2>



Effects of Vermicompost and Mineral Water on the Growth Parameters of the KDML 105 Rice Cultivar

DUANGNAPA SAIYAKIT

Department of Soil Sciences and Environment, Faculty of Agriculture, Khon Kean University, Khon Kean, Thailand

CHULEEMAS BOONTHAI IWAI*

Department of Soil Sciences and Environment, Faculty of Agriculture, Khon Kean University, Khon Kean, Thailand

Email: chuleemas1@gmail.com

Received 21 February 2022 Accepted 20 June 2022 (*Corresponding Author)

Abstract The purpose of this research aimed to study the effects of vermicompost and mineral water from a wellspring in Ban Haubueng Community Forest, Nampong District, Khon Kaen Province, Thailand on the growth parameters of rice cultivar KDML 105. The rice growth experiments were conducted in a completely randomized design, with four irrigation treatments: irrigation water (T0), irrigation water with vermicompost (T1), mineral water (T2), and mineral water with vermicompost (T3) under greenhouse conditions. The results found that the application of the vermicompost with mineral water gave the highest rice growth parameters; such as plant height, panicles, grains per panicle, and number of tillers per hill, with a significant difference of $p \leq 0.05$. The highest plant height (139.63 cm.) was found in the T1 treatment, and the highest number of tillers per hill and grain weight were found in the T3 treatment at 7.00 and 175.28 grams per plot, respectively; as vermicompost is a rich source of readily available nutrients and contains growth hormones. Although the application of mineral water produced lower plant heights than that of the irrigation water, the tillered rice demonstrated an increased number of tillers per hill and grains per panicle. The results of this experiment revealed that the addition of vermicompost and mineral water had significant positive effects on plant growth parameters of rice. It can conclude that the utilization of mineral water from the wellspring community forest with vermicompost could help farmers to increase rice production.

Keywords vermicompost, mineral water, rice production

INTRODUCTION

Rice is the main staple food in Asia (Ruan et al., 2021), including Thailand, which represents one of the world's largest consumers and top rice exporters (TREA, 2022). The growth of rice depends on the practice of nutrient management in cropping systems (Naivikul, 2007). Chemical fertilizers are applied for rice growth and yield, but in the long term, may damage soil property and increase investment costs. We hypothesized that the application of vermicompost could help improve this issue. Vermicompost is an organic fertilizer, rich in nutrients, used to improve soil. Vermicomposts can significantly influence the growth and productivity of plants (Kale et al., 1992; Kalembasa, 1996; Sinha et al., 2002) due to their micro and macro elements, vitamins, enzymes, and hormones (Makulec, 2002). There are contain nutrients such as nitrates, exchangeable phosphorus, soluble potassium, calcium, and magnesium in plant available forms (Orozco et al., 1996; Edwards, 1998). All of its nutrients are in a readily available form, thereby enhancing their uptake by plants and, in turn, crop yield (Bejbaruha et al., 2013). Several studies have determined that enhancing Nutrient nitrogen, phosphorus, and potassium (NPK) uptake increased rice yields through the application of vermicompost (Srivastava et al., 2014; Bejbaruah et al., 2013). Vermicompost production is not complicated and requires a low investment (Iwai et al., 2011). In this study, we also applied

mineral water in the cropping system. Mineral water is a natural water source from the local village forest, which farmers use for both consumption and agriculture. Through analysis, the mineral water's composition was found to contain several nutrients; one of which is silicon, known for its role in alleviating the negative stresses, both biological and physical (Pati et al., 2016), in many plant species (Epstein., 1999). Rice is typically high in silicone and can accumulate up to 10% of its shoot dry weight (Ma et al., 2002).

OBJECTIVE

The purpose of our research was to study the effects of vermicompost and mineral water from the wellspring in the Ban Haubueng Community Forest, Nampong District, Khon Kaen Province, Thailand; on the growth of rice cultivar KDML 105.

METHODOLOGY

Plant Materials and Experimental Design

The seeds of rice cultivar KMDL 105, which are widely planted in Northeast Thailand, were used as plant materials. After soaking in tap water for 24 hours, the seeds were germinated at 30°C for 12 hours and then sown in a basin. The seedlings were then transported to plastic pots 30 cm in height and 30 cm in diameter, and grown under greenhouse conditions. The experiment was conducted in the Faculty of Agriculture, Khon Kean University, Khon Kean Province, Thailand. Six treatments were adopted in the present study, and are described as follows: (T0) irrigation water; (T1) irrigation water with vermicompost; (T2) mineral water; and (T3) mineral water with vermicompost.

The vermicompost used herein was produced by the Vermitechnology for Sustainable Agriculture and Environment, Faculty of Agriculture, Khon Kean University, Khon Kaen, Thailand. The nutrients of vermicompost were analyzed and found various nutrients, as follows: pH 9.05; EC (0.87 dS/m); Organic matter (11.14%); Total nitrogen (7.64 g kg⁻¹); Total phosphorus (11.27 g kg⁻¹); Total potassium (6.18 g kg⁻¹); Magnesium (4.34 g kg⁻¹); and Calcium (64.27 g kg⁻¹). Irrigation water and mineral water were collected from the Ban Haubueng, Nampong District, Khon Kaen Province. The sources of irrigation water come from irrigation canal from Nong Wai Dam as a resources water for agriculture. The mineral water from the wellspring in Ban Haubueng community forest as a naturally occurring water sources. The chemical composition of mineral water was found to contain numerous nutrients, as follows: pH 6.81; EC (0.08 dS/m); NO⁻³ (6.28 mg/L); Cu (0.002 mg/L); Mn (0.008 mg/L); Ni (0.003 mg/L); SiO₂ (17.016 mg/L); and Si (7.954 mg/L).

Measurements of Agronomic Traits

Rice (KDML 105) from each treatment was collected; and the plant height, biomass, number of tillers per hill, fill grains, 100-grain weight, and grain weight were measured. The biomass was measured after being oven-dried at 70°C for 48 hours.

Statistical Analyses

All experimental data were subjected to a one-way analysis of variance (ANOVA) with Statistix 10 software. Differences among means were separated using the least significant difference (LSD) test at a 5% probability level.

RESULTS

Growth Parameters of the rice cultivar KDML 105

The plant height, biomass, number of tillers per hill, fill grains, 100 grains weight, and grain weight of the KDML 105 rice cultivar are presented in Table 1. Plant height, fill grains, and grains per panicle were significantly ($p < 0.05$) increased through the application of the vermicompost (T1, T3). The irrigation water application (T0, T1) presented significantly higher height, fill grains, and grains per panicle than that of the mineral water application (T2, T3). The highest plant height (139.63 cm.) was found in the T1 treatment. However, the mineral water treatments produced significantly ($p < 0.05$) higher amounts of biomass, number of tillers per hill, and grain weight than those found in T0 and T1. The highest number of tillers per hill and grain weight were found in the T3 treatment at 7.00 and 175.28 g. per plot, respectively. Regarding 100 Grain weight, there were no significant differences between treatments. The highest 100 Grain weight (2.49 g.) was found in the T3 treatment.

Table 1 Effects of vermicompost and mineral water on plant height, biomass, number of tillers per hill, fill grains, 100 grain weight, and grain weight of rice cultivar KDML 105

Treatment	Plant height	Biomass (g./plot)	Number of tillers per hill	Fill grains (%)	100 Grain weight (g.)	Grains per panicle	Grain weight (g./plot)
T0 (irrigation water)	132.85 AB	53.03 B	3.75 B	61.81 A	2.42 AB	108.00 A	125.31 C
T1 (irrigation water with VC)	139.63 A	58.04 B	3.88 B	63.18 A	2.35 B	119.44 A	154.01 B
T3 (mineral water)	127.13 B	87.80 A	7.00 A	31.87 B	2.49 A	78.13 B	175.28 A
T4 (mineral water with VC)	130.19 A	86.19 A	7.00 A	38.32 B	2.45 AB	98.81 AB	172.57 A

Treatments with the same letters are not significantly different at ($P < 0.05$). VC = Vermicompost.

DISCUSSION

The present study applied vermicompost and mineral water in the growth of rice cultivar KDML 105. Our results showed that plant height, fill grains, and grains per panicle increased with the application of vermicompost (T1, T3). These results are consistent with the previous studies that demonstrated that the application of vermicompost enhanced the growth and development of crops (Blouin et al., 2019; Ruan et al., 2021; and Suleerak and Suchada, 2014), as a result of the rich source of readily available nutrients and growth hormones (Gandhi et al., 1997; Edwards, 1998) present in the vermicompost. There is further expanded upon the composition of vermicompost as organic fertilizer with multiple mineral elements (Patnaik et al., 2020; Ruan et al., 2021). As previous studies reported, the application of silicon fertilizer alleviated negative stress effects and increased the grain and straw yields, plant height, number of tillers, number of panicles, and 1000-grain weight of rice (Ma and Takahashi, 2002; Pati et al., 2016; Cuong et al., 2017). There is research determined that the accumulation of silicon on the cell walls of the epidermal cells of rice leads to enhanced strength and rigidity of the cells, resulting in increased resistance to pests and diseases, lodging, improved light interception, and reduced transpiration (Meena et al., 2014; Sathe et al., 2021). We, therefore, surmised that the application of vermicompost and mineral water might improve the stress resistance of rice; however, more studies should be performed at the physiological level to further support this hypothesis.

CONCLUSION

The growth parameters of rice cultivar KDML 105; including plant height, panicles, grains per panicle, and number of tillers per hill, improved through the application of vermicompost and

mineral water. Therefore, the utilization of mineral water from the wellspring community forest with vermicompost is recommended as a viable agronomic practice to assist farmers in increasing rice production. We train to produce their own vermicompost for using with mineral water to produce quality rice.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to both the Integrated Land and Water Resource Management Research and Development Center in Northeastern Thailand and Vermitechnology Centre for Sustainable Agriculture and Environment, Faculty of Agriculture, Khon Kean University, Khon Kaen, Thailand.

REFERENCES

- Bejbaruah, R., Sharma, R.C. and Banik, P. 2013. Split application of vermicompost to rice (*Oryza sativa* L.), Its effect on productivity, yield components, and N dynamics. *Organic Agriculture*, 3, 123-128, Retrieved from DOI <https://doi.org/10.1007/s13165-013-0049-8>
- Blouin, M., Barrere, J., Meyer, N., Lartigue, S., Barot, S. and Mathieu, J. 2019. Vermicompost significantly affects plant growth, A meta-analysis. *Agronomy for Sustainable Development*, 39, 34, Retrieved from DOI <https://doi.org/10.1007/s13593-019-0579-x>
- Cuong, T.X., Ullah, H., Datta, A. and Hanh, T.C. 2017. Effects of silicon-based fertilizer on growth yield and nutrient uptake of rice in tropical zone of Vietnam. *Rice Science*, 24 (5), 283-290, Retrieved from DOI <https://doi.org/10.1016/j.rsci.2017.06.002>
- Edwards, C.A. 1988. Breakdown of animal, vegetable and industrial organic wastes by earthworms. In Edwards, C.A. and Neuhauser, E.F. (Eds.), *Earthworms in Waste and Environmental Management*, 21-31, SPB Academic Publishing, The Hague, Netherlands.
- Epstein, E. 1999. Silicon. *Annual Review of Plant Physiology and Plant Molecular Biology*, 50, 641-664, Retrieved from DOI <https://doi.org/10.1146/annurev.arplant.50.1.641>
- Gandhi, M., Sangwan, V., Kapoor, K.K. and Dilbaghi, N. 1997. Composting of household wastes with and without earthworms. *Environment and Ecology*, 15 (2), 432-434.
- Iwai, C.B., Mongkol, T., Surasak, S. and Nuntawut, C. 2011. Fertilizer production by earthworms, Management waste soil produces good and safe. Khon Kaen. Department of Plant Science and Resources Agriculture, Faculty of Agriculture, Khon Kaen University, Thailand.
- Kale, R.D., Mallesh, B.C., Bano, K. and Bagyaray, D.J. 1992. Influence of vermicompost application on the available macronutrients and selected microbial populations in paddy field. *Soil Biology and Biochemistry*, 24 (12), 1317-1320, Retrieved from DOI [https://doi.org/10.1016/0038-0717\(92\)90111-A](https://doi.org/10.1016/0038-0717(92)90111-A)
- Kalambasa, D. 1996. The influence of vermicomposts on yield and chemical composition of tomato. *Zesz Probl Post Nauk Roln*, 437, 249-252.
- Ma, J.F. and Takahashi, E. 2002. *Soil, fertilizer, and plant silicon research in Japan*. Elsevier, ISBN 978-0-444-51166-9, Netherlands.
- Ma, J.F., Tamai, K., Ichii, M. and Wu, G.F. 2002. A rice mutant defective in Si uptake. *Plant Physiol*, 130 (4), 2111-2117, Retrieved from DOI <https://doi.org/10.1104/pp.010348>
- Makulec, G. 2002. The role of *Lumbricus rubellus* Hoffm. in determining biotic and abiotic properties of peat soils. *Polish Journal of Ecology*, 50 (3), 301-339.
- Meena, V.D., Dotaniya, M.L., Coumar, V., Rajendiran, S., Ajay, S., Kundu, S. and Rao, A.S. 2014. A case for silicon fertilization to improve crop yields in tropical soils. *Proceedings of the National Academy of Sciences, India Section B, Biological Sciences*, 84, 505-518, Retrieved from DOI <https://doi.org/10.1007/s40011-013-0270-y>
- Naivikul, O. 2007. *Rice, science and technology* (2nd ed.). Kasetsart University Press, Bangkok, Thailand.
- Orozco, F.H., Cegarra, J., Trujillo, L.M. and Roig, A. 1996. Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*, Effects on C and N contents and the availability of nutrients. *Biology and Fertility of Soils*, 22, 162-166, Retrieved from DOI <https://doi.org/10.1007/BF00384449>
- Pati, S., Pal, B., Badole, S., Hazra, G.C. and Mandal, B. 2016. Effect of silicon fertilization on growth, Yield and nutrient uptake of rice. *Communications in Soil Science and Plant Analysis*, 47 (3), 284-290, Retrieved from DOI <https://doi.org/10.1080/00103624.2015.1122797>

- Patnaik, P., Abbasi, T. and Abbasi, S.A. 2020. Vermicompost of the widespread and toxic xerophyte prosopis (*Prosopis juliflora*) is a benign organic fertilizer. Journal of Hazardous Materials, 399, 122864, Retrieved from DOI <https://doi.org/10.1016/j.jhazmat.2020.122864>
- Ruan, S., Wu, F., Lai, R., Tang, X., Luo, H. and He, L. 2021. Preliminary application of vermicompost in rice production, Effects of nursery raising with vermicompost on fragrant rice performances. Agronomy, 11 (6), 1253, Retrieved from DOI <https://doi.org/10.3390/agronomy11061253>
- Sathe, A.P., Kumar, A., Mandlik, R., Raturi, G., Yadav, H., Kumar, N., Shivaraj, S.M., Jaswal, R., Kapoor, R., Gupta, S.K., Sharma, T.R. and Sonah, H. 2021. Role of silicon in elevating resistance against sheath blight and blast diseases in rice (*Oryza sativa* L.). Plant Physiology and Biochemistry, 166, 128-139, Retrieved from DOI <https://doi.org/10.1016/j.plaphy.2021.05.045>
- Sinha, R.K., Heart, S., Agarwal, S., Asadi, R. and Carretero, E. 2002. Vermiculture and waste management, Study of action of earthworms *Elsinia foetida*, *Eudrilus euginae* and *Perionyx excavatus* on biodegradation of some community wastes in India and Australia. Environment Systems and Decisions, 22, 261-268, Retrieved from DOI <https://doi.org/10.1023/A:1016583929723>
- Srivastava, V.K., Singh, J.K. Bohra, J.S. and Singh, S.P. 2014. Effect of fertilizer levels and organic sources of nitrogen on production potential of hybrid rice (*Oryza sativa*) and soil properties under the system of rice intensification. Indian Journal of Agronomy, 59, 607-612.
- Suleerak, A. and Suchada, S. 2014. Effects of a vermicomposts from earthworms on changes of soil physical properties and improve soil structure. Maejo university, Thailand.
- Thai Rice Exporters Association. 2022. Rice exports by destination 2019-2021. Bangkok, Thailand, Retrieved from <http://www.thairiceexporters.or.th/export%20by%20country%202021.html>



Benefits of Applying Microbial Fuel Cell Technology in Organic Farming for Sustainable Agriculture

NARONG TOUCH*

*Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: nt207118@nodai.ac.jp*

TAKAHIKO NAKAMURA

Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

Received 14 January 2022 Accepted 27 June 2022 (*Corresponding Author)

Abstract Increasing the productivity of organic farming is a strategy to achieve sustainable agriculture. However, it is necessary to maintain soil redox potential (ORP) in continuously oxidized conditions and to promote bacterial metabolisms in soils to increase productivity. Previously, applying microbial fuel cell technology (MFCT) into sediment improved ORP and benthos survival in the sediment. It is thought that these positive effects of MFCT can also provide many benefits for soil cultivation in organic farming. This study aims to examine the changes in the biochemical properties of soil following MFCT application. In laboratory experiments, MFCT was applied to cow manure compost-mixed andosol. An anode (oxidation reaction) and a cathode (reduction reaction) were installed in the soil, and a 1.5-V solar cell was used to produce an electric current between the two electrodes. Three months after MFCT application, the chemical properties and adenosine triphosphate (ATP) of the soil were measured. Our results showed an electric potential distribution in the soil, and the soil located within 20 cm of the electrode was strongly affected by the electrode reaction. This suggests that applying MFCT to soil can change the soil's redox conditions. The ATP and ammonium concentrations increased, suggesting bacterial activation and enhanced organic matter decomposition in the soil. It is recommended that farmers should apply MFCT into soils for enhancing bacterial metabolism and increasing organic matter decomposition in soils.

Keywords microbial fuel cell, organic farming, soil reduction, soil oxidation, nitrogen release, bacterial activation

INTRODUCTION

According to the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), organic farming is a strategy to achieve sustainable agriculture. However, the ratio of total organic farmland to all cultivated land remains low. In 2018, the ratio was 0.2% in Japan and 1.5% worldwide. On the basis of the questionnaire survey conducted by MAFF (2018), technologies to enhance productivity and implementation systems are required to facilitate organic farming. This study focuses on technology to enhance the productivity of organic farming.

Understanding of the soil chemical environment (SCE) is useful to ensure healthy soil that can sustain crop production (Yan and Hou, 2018). Because a decline in soil fertility results in a decrease in productivity (Buresh et al., 1997), soil fertility and health management play an important role in realizing sustainable agriculture (Prasad and Power, 1997). In organic farming, as nutrients are supplied by the decomposition of organic matter, facilitating this decomposition plays an important role in providing higher productivity. However, the SCE varies with the decomposition of organic matter (soil reduction). This variation affects biological soil properties, resulting in a decrease in the decomposition rate of organic matter. Therefore, technology that can reduce changes in the SCE and continuously activating bacterial metabolism is required to provide higher productivity in organic farming.

Numerous studies have reported that applying microbial fuel cell technology (MFCT) to sediment facilitates the decomposition of organic matter and increases the redox potential of the sediment (Sacco et al., 2012; Sajana et al., 2013; Touch et al., 2014). Furthermore, MFCT has been proven to effectively improve the benthic habitat environment in highly reduced sediment (Touch et al., 2018a). It is thought that these benefits of MFCT would be also useful for organic farming.

OBJECTIVE

This study aims to examine the benefits of applying MFCT for organic farming. Specifically, we examined changes in the soil redox potential, biological properties, and nutrient release following MFCT application. This was conducted by applying MFCT into cow manure compost-mixed andosol with a generated electric current for 3 months.

METHODOLOGY

Experimental Procedures and Operations

Commercial products, i.e., cow manure compost and andosol, were used in laboratory experiments. First, cow manure compost was mixed with andosol at a volume ratio of 47% (generally, 40% to 60% is used). The mixture was then used in the experiments which were conducted under three conditions, i.e., without treatment (Case 1), treated with a solar cell (Case 2), and treated with a sediment microbial fuel cell (Case 3). Case 2 was conducted in duplicate. In Case 1, no electrode was installed in the mixture (Fig. 1a).

In Case 2, two electrodes were installed in the soil layer (Fig. 1b). For generating an electrical current, one of the both electrodes were connected to the positive, and another was connected to the negative terminals of a 1.5-V solar cell (Tamiya, 1.5 V) using the circuit shown in Fig. 1b. A 2.2- Ω external resistance was loaded between the anode and solar cell. In Case 3, an electrode was placed in the soil layer (anode), and another was placed near the water surface (cathode), as shown in Fig. 1c. For generating an electrical current, a 2.2- Ω external resistance was loaded between the anode and cathode. This system is generally called a sediment microbial fuel cell (SMFC). Note that both systems used in Cases 2&3 are different types of MFCT in which the system of Case 2 used a solar cell as an external power supply. Here the solar cell was used following the study by Touch et al. (2020), who suggested that using a solar cell increased the electric current of the SMFC and improved the decomposition of organic matter present in paddy soils. The electrode material was carbon cloth (News Company, PL200-E), which was heated at 500°C for 1 h prior to use to improve its performance, as was suggested by Nagatsu et al. (2014). The heated carbon cloth with a width of 20 cm and height of 10 cm was separated into fibers to form a brush-type electrode (Fig. 1d). The electrode was placed in a plastic net (1-mm mesh) and installed in the soil layer.

After the installation of both electrodes, the container was filled with tap water. As a result, a 2-cm water layer was formed on the soil surface, which can prevent the soil from drying due to evaporation. The experiments were conducted from June to November in 2020. The voltage at both terminals of the external resistance was measured every 15 min using a voltage logger (T&D Corp., MCR-4V) to calculate the circuit current according to the Ohm's law. The current density was obtained by dividing the current by the surface area of the electrode, i.e., 0.02 m². To measure the anode potential of each case, the anode and a reference electrode (Toyo Corp., W-RE-7A) placed in the overlying water were connected to the voltage logger.

Analyses

Three months after the experiments started, soil sampling was conducted. First, 1 cm of surface soil was removed, and then, pH and redox potential (ORP) were measured using a pH/ORP meter (Horiba, D-50) at intervals of 5 cm from the anode. Soil samples were collected (Fig. 1e) after the pH and ORP measurements. Only half-length of the soil layer should be collected for examining

the effects of solar cell or SMFC on the soil properties. However, in Case 2 (SC), the soils between the electrodes were collected to determine the effective range of electrode reaction. Next, each soil sample was centrifuged at 6000 rpm for 5 min (As one, CN-2060) to extract the porewater. Finally, the nutrient concentration (phosphate, PO_4^{3-} ; ammonium, NH_4^+), and adenosine triphosphate (ATP) were measured. PO_4^{3-} and NH_4^+ concentrations were measured using PACKTEST (Kyoritsu Corp., WAK). ATP concentration was measured using a lumitester (Kikkoman, Lumitester-Smart), and the result represents the sum concentration of adenosine triphosphate, adenosine diphosphate, and adenosine monophosphate.

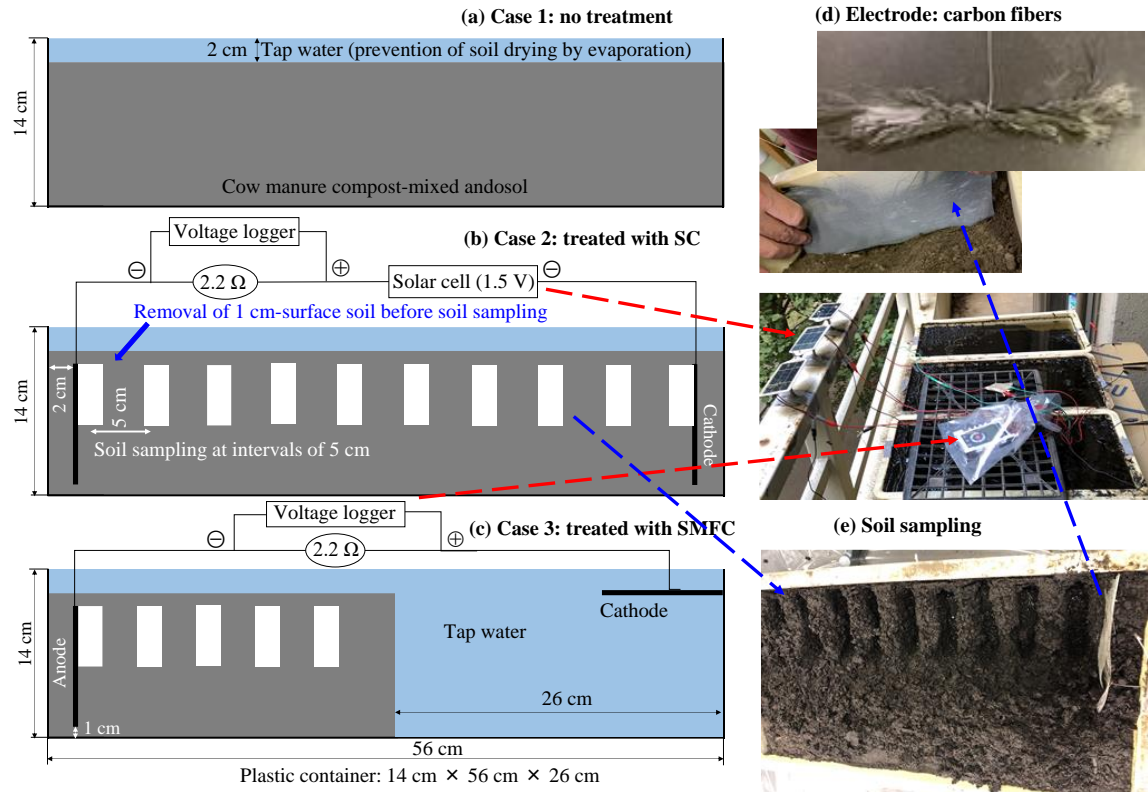


Fig. 1 Experimental devices and operations

RESULTS AND DISCUSSION

Comparison of Current Density Generated Using SMFC and a Solar Cell

Figure 2 depicts the temporal changes in the current densities generated using the SMFC and solar cell during the first 30 days of the experiments.

As can be seen from the figure, the maximum current density generated by the SMFC was approximately 60 mA/m^2 , which increased to 200 mA/m^2 when using the solar cell. During the first month of the experiments, the total electric charge was $50,415 \text{ C/m}^2/\text{month}$ when the SMFC was used whereas the total was $59,220 \text{ C/m}^2/\text{month}$ when the solar cell was used. Although, more than three times the current density was observed, only a 1.17-fold change in the total electric charge was found between both cases. This is because no electrical current was generated at night when the solar cell was used.

Changes in Redox Conditions at the End of the Experiment

Figure 3 shows the changes in pH and ORP due to current generation at the end of the experiment. In the figure, 0 and 45 cm refer to the soil samples at the anode and cathode, respectively (Case 2). In Fig. 3a, the pH at the anode was 6.97 for Case 1 (without current generation), which decreased

to 6.44 when using the SMFC (Case 3) and to 6.39 when using the solar cell (Case 2). In Case 3, the large increases in pH at distances greater than 10 cm were due to the effects of cathode water (Fig. 1c).

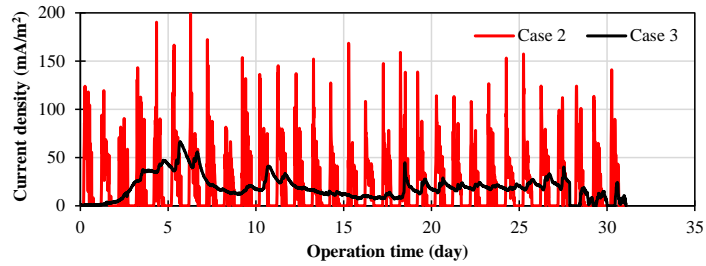


Fig. 2 Comparison of current densities generated using the SMFC and solar cell

In contrast to the literature, our results showed no increase in ORP following SMFC application. However, increases in ORP were observed when the solar cell was used. The increases in ORP were caused by large variations in the electrode potential due to the use of the solar cell (Fig. 4). In Fig. 4, the anode potential was in the ranges from 0.2 to 0.4 V and -0.2 to 0.8 V vs. Ag/AgCl when using the SMFC (Case 3) and the solar cell (Case 2), respectively. The oxidation reactions at the anode following current generation caused the decrease in pH and increase in ORP. These results suggest that the solar cell can be used to effectively control the soil redox conditions, i.e., pH and ORP. From the ORP distribution, it is thought that the soil located within 20 cm of the electrode was affected by current generation using the solar cell. It is expected that nutrient release and microbial activation differ in response to these changes in pH and ORP.

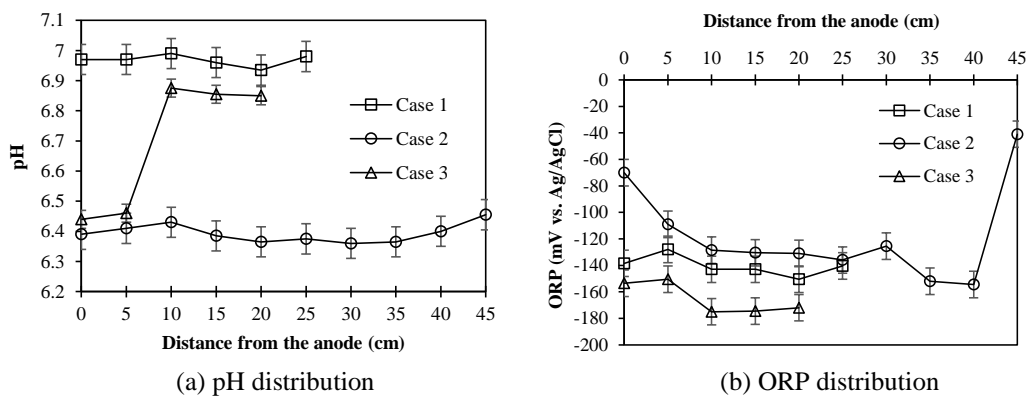


Fig. 3 Changes in pH and ORP due to current generation at the end of the experiment

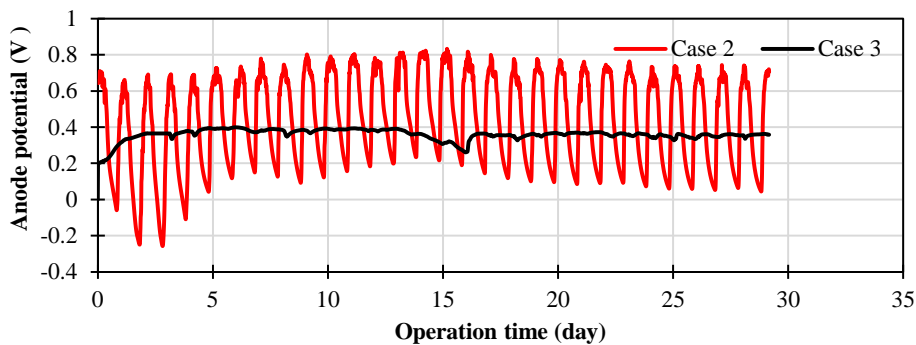


Fig. 4 Temporal changes of the anode potential during the first month of the experiment

Nutrient Release due to Current Generation

Figure 5 shows the distributions of ammonium (NH_4^+) and phosphate (PO_4^{3-}). No differences were observed between Case 1 and Case 3 (differences were within the error range), suggesting that the SMFC had little effect on the decomposition of organic matter. Interestingly, a large increase in NH_4^+ concentration was observed between Cases 1 and 2, at distances from 15 to 30 cm from the anode. A 2-fold increase in NH_4^+ concentration was observed 20 cm from the anode. However, the PO_4^{3-} concentrations in all cases were on the same order of magnitude (Fig. 5b).

The released NH_4^+ is believed to arise from the decomposition of organic matter. Even though the generated electric charges were on the same order of magnitude (Case 2: 59,220 C/m²/month; Case 3: 50,415 C/m²/month), the decomposition behavior of organic matter differed. This may be due to the differences in electrode potential between Cases 2 and 3 (Fig. 4). The decomposition of organic matter was facilitated when the solar cell was used, which is in good agreement with the results obtained by Touch et al. (2020). According to Touch et al. (2018b), the lower NH_4^+ concentration near both electrodes (Fig. 5a) may be due to the oxidation of NH_4^+ at the electrodes due to the high electrode potential when the solar cell is used (Fig. 4).

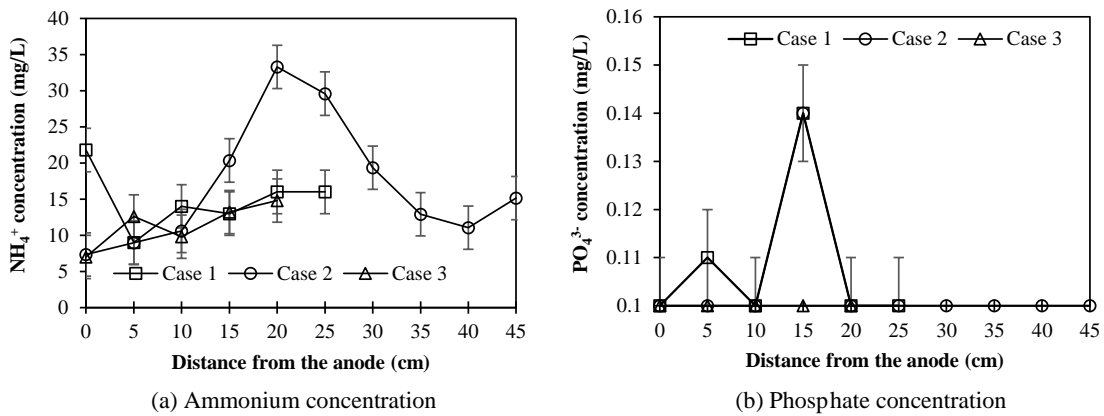


Fig. 5 Comparison of nutrient concentration distributions of each case

Changes in ATP due to Current Generation

Figure 6 illustrates the ATP distribution of each case. Similar to the distribution of NH_4^+ , almost no difference in ATP was found between Cases 1 and 3. However, two to threefold increases in ATP were observed when the solar cell was used (Case 2). These results suggest that using the solar cell can provide a better biological environment, resulting in a higher decomposition rate of organic matter. This may be the cause of the higher NH_4^+ concentration observed when the solar cell was used (Fig. 5a, Case 2).

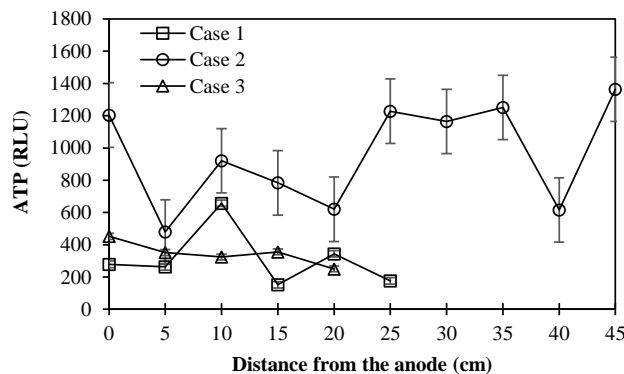


Fig. 6 Changes in ATP due to current generation

CONCLUSIONS

Laboratory experiments were conducted to examine the benefits of applying MFCT in organic farming. Specifically, changes in the soil redox potential, biological properties, and nutrient release following the application of MFCT to cow manure compost-mixed andosol were investigated. Similar to previous results when applying MFCT into littoral sediments, an increase in ORP near an electrode was observed. Following current generation using a solar cell, an ORP distribution was formed in the soil, and the soil located within 20 cm from the electrode was affected by the electrode reaction. This suggests that applying MFCT to soil can change the soil's redox conditions. The ATP and ammonium concentrations increased because of the current generated by the solar cell, suggesting bacterial activation and enhanced organic matter decomposition in the soil. It can be concluded that applying MFCT can control soil biochemical conditions and can enhance bacterial metabolism and organic matter decomposition in soils, which are the most important factors in organic farming.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the partial funding from Tokyo University of Agriculture: FY2021 Grant-in-Aid for Sustainable Agriculture Research Projects. The authors also would like to thank the students of the Rural Environmental Engineering Laboratory, Tokyo University of Agriculture, for their efforts in collecting data.

REFERENCES

- Buresh, R.J., Sanchez, P.A. and Calhoun, F. 1997. Replenishing soil fertility in Africa. Volume 51, Soil Science Society of America, ISBN 9780891189466, USA.
- Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF). 2018. The promotion statue of organic farming. Ministry of Agriculture, Forestry and Fisheries of Japan, Retrieved from https://www.maff.go.jp/j/seisan/kankyo/yuuki/attach/pdf/chosa_jichitai-48.pdf
- Nagatsu, Y., Tachiuchi, K., Touch, N. and Hibino, T. 2014. Factors for improving the performance of sediment microbial fuel cell. *Journal of Japan Society of Civil Engineers Ser B2 (Coastal Engineering)*, 70 (2), 1066-1070, Retrieved from DOI https://doi.org/10.2208/kaigan.70.I_1066 in Japanese
- Prasad, R. and Power, J.F. 1997. Soil fertility management for sustainable agriculture. Lewis Publishers, CRC Press, ISBN 9781566702546, New York, USA.
- Sacco, N.J., Figuerola, E.L.M., Pataccini, G., Bonetto, M.C., Erijman, L. and Cortón, E. 2012. Performance of planar and cylindrical carbon electrodes at sedimentary microbial fuel cells. *Bioresource Technology*, 126, 328-335, Retrieved from DOI <https://doi.org/10.1016/j.biortech.2012.09.060>
- Sajana, T.K., Ghangrekar, M.M. and Mitra, A. 2013. Application of sediment microbial fuel cell for in situ reclamation of aquaculture pond water quality. *Aquacultural Engineering*, 57, 101-107, Retrieved from DOI <https://doi.org/10.1016/j.aquaeng.2013.09.002>
- Touch, N., Hibino, T., Kinjo, N. and Morimoto, Y. 2018. Exploratory study on improving the benthic environment in sediment by sediment microbial fuel cells. *International Journal of Environmental Science and Technology*, 15, 507-512, Retrieved from DOI <https://doi.org/10.1007/s13762-017-1418-8>
- Touch, N., Hibino, T., Nagatsu, Y. and Tachiuchi, K. 2014. Characteristics of electricity generation and biodegradation in tidal river sludge-used microbial fuel cells. *Bioresource Technology*, 158, 225-230, Retrieved from DOI <https://doi.org/10.1016/j.biortech.2014.02.035>
- Touch, N. and Nakamura, T. 2020. Decomposition of organic matter in steelmaking slag-used sediment microbial fuel cells. *International Journal of Environmental Protection*, 10 (1), 1-6, Retrieved from <http://paper.academicpub.org/PaperInIssue?IssueId=1793>
- Touch, N., Yamaji, S., Nishimura, K., Sunada, Y. and Hibino, T. 2018. Remediation of sediment deposited near sewage outlet with solar cell-combined sediment microbial fuel cells. *International Journal of Environmental Protection*, 8 (1), 18-24, Retrieved from <http://paper.academicpub.org/Paper?id=17688>
- Yan, B. and Hou, Y. 2018. Soil chemical properties at different toposequence and fertilizer under continuous rice production, A review. *IOP Conference Series, Earth and Environmental Science*, 170, 032107 (5 pages), Retrieved from <https://iopscience.iop.org/article/10.1088/1755-1315/170/3/032107/pdf>



Evaluation of Soil Erosion Risk in the City of Cobija, Bolivian Amazonia Using RUSLE and GIS

JUAN UEGO PEREZ

*Graduate School of Agro-Environmental Science, Tokyo University of Agriculture, Japan
E-mail: uego.juan@gmail.com*

MACHITO MIHARA*

*Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
E-mail: m-mihara@nodai.ac.jp*

Received 17 May 2022 Accepted 4 July 2022 (*Corresponding Author)

Abstract In recent years, deforestation has increased remarkably in the region of Bolivian Amazonia. So, research interests have been focused on how the deforestation affects the soil erosion risk. Accordingly, this study was conducted in the city of Cobija, Bolivian Amazonia to evaluate the erosion risk employing the Revised Universal Soil Loss Equation (RUSLE). For calculating the rainfall-runoff erosivity factor (R), an empirical model based on measured annual precipitation was applied. To calculate the soil erodibility factor (K), the experimental models based on soil properties (composition of sand-silt-clay percentages, organic matter, structure, and permeability of the soil profile) was employed. Also, to generate the topographic factor (LS), a digital elevation model (DEM) image was applied. In addition, the cover management factor (C) of each land use and the support practice factor (P) for different conservation practices were based on the outcomes from former studies. The results of RUSLE analysis, the annual soil loss per unit area (A) was in the range of of the medium soil loss from $5 < 7$ t/ha/year. With accelerating soil erosion, soil organic matters as well as soil aggregate have been lost, and soil loss would be severer gradually. So, effective soil conservation measures should be implemented for minimizing the loss of soil organic matters as well as soil aggregate.

Keywords RUSLE, soil loss, amazonia, erosion

INTRODUCTION

Soil erosion is one of the main global threats to water and food security (Amundson et al., 2015). Soil provisioning, regulatory, and supporting services are essential for sustaining water, food, and energy security nexus (Keesstra et al., 2016). In recent years, Bolivia has been recognized as one of the countries that has the highest rate of deforestation in the world, the city of Cobija is located in the Amazonia, has experienced annually expansion of the city simultaneously with the expansion of the agricultural frontier and generated deforestation in the areas. The adverse influences of widespread soil erosion on soil degradation, agricultural production, water quality, hydrological systems, and environment, have long been recognized as severe problems for human sustainability. However, estimation of soil erosion loss is often difficult due to the complex interplay of many factors, including climate, land cover, soil, topography, and human activities. This paper describes research that seeks to evaluate the erosion risk in the city of Cobija - Pando, Bolivian Amazonia and apply the Revised Universal Soil Loss Equation (RUSLE) for estimate the soil loss.

OBJECTIVE

The objective is to apply the Revised Universal Soil Loss Equation (RUSLE), and geographic information system (GIS) to determine the risk of erosion and the soil loss in the city of Cobija Bolivian Amazonia area. Cobija is a Bolivian City, capital of the Department of Pando and the

Province of Nicolás Suárez. Cobija has experienced high deforestation rates during the past two decades (Bolivian Institute, 2015) following the national strategy of regional initiated by the Bolivia Government in 2015 played a major role in this process. The local farmers transformed the forested landscape slowly into urban city the climate in this study area is classified as equatorial hot and humid with tropical transition. A well-defined dry season lasts from June to August, and the annual average precipitation is 2016 mm (Mayorality of Cobija, 2020). The surface of the research area is 411 km², the annual average temperature is 32°C - 22°C, and monthly averages for air moisture range from 80 to 85 percent. The terrain is undulating, ranging from 100 to 120 m above sea-level.

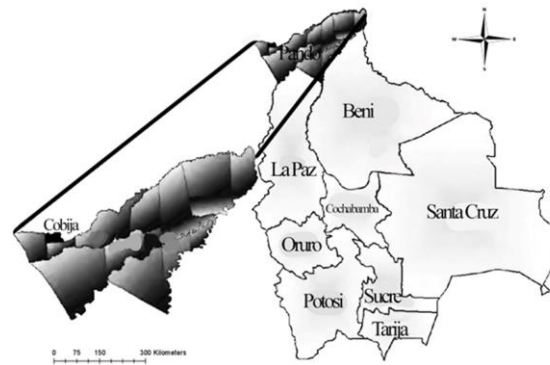


Fig. 1 Location of the study area in the city of Cobija, Bolivian Amazonia

METHODOLOGY

Brief Description of RUSLE

The RUSLE represents how climate, soil, topography, and land use affect rill and interrill soil erosion caused by raindrop impact and surface runoff (Renard et al., 1997). It has been extensively used to estimate soil erosion loss, to assess soil erosion risk, and to guide development and conservation plans in order to control erosion under different land-cover conditions, such as croplands, rangelands, and disturbed forest lands (Millward and Mersey, 1999; Boggs et al., 2001; Mati and Veihe, 2001; Angima et al., 2003). The RUSLE is expressed by Equation 1.

$$A = R \times K \times L \times S \times C \times P \quad \text{Eq. 1}$$

Where A is the average annual soil loss in tons per hectare; R is the rainfall-runoff erosivity factor; K is the soil erodibility factor; L is the slope length factor; S is the slope steepness factor; C is the cover management factor; and P is the support practice factor. Table 1 summarized the calculating methods for estimating each factor.

Table 1 Summary of calculating methods for applying RUSLE in this study

	Methods	References
R	Using average monthly precipitation and average annual precipitation Using a regression model based on measured annual precipitation	Renard and Fremund, 1994
K	Using the experimental models based on soil properties (composition of sand–silt–clay percentages, organic matter, structure, and permeability of the soil profile)	Wischmeier and Smith, 1978
LS	Estimated from actual field measurements of length and steepness Calculated from DEM data with various approaches	Hickey, 2000; Van Remortel et al., 2001
C	Land use comparison table	Silva et al., 2007
P	Table of P values for different conservation practices	Bertoni and Lombardi Neto, 1985

RESULTS AND DISCUSSION

Rainfall and Runoff Erosivity R Factor

The rainfall runoff erosivity was calculated from Equation 2 as shown below.

$$EI_{monthly} = 89.823 \left(\frac{Pm^2}{Pa} \right)^{0.759} \quad \text{Eq. 2}$$

Where EI is the monthly mean of the erosion index for the month considering (mm/ha), Pm is the average precipitation of the month considering (mm), Pa is the average annual precipitation (mm) at the Pelvimetric Station located in Cobija. Based on monthly results, the rainfall runoff erosivity was calculated annually. Using the equation, the annual average of rainfall runoff erosivity was determined with the data of the last 5 years as shown in Table 2, the average R factor determined was 8929.2 MJ mm/h ha per year and it was considered the EI value was in the highest class describing the potential of intense erosion.

Table 2 Annual rainfall and rainfall runoff erosivity

Year	Annual Rainfall Pa (mm)	Annual EI (Mj.mm/h ha)
2017	1903.1	9054.6
2018	1687.5	7955.3
2019	2002.2	9628.6
2020	1385.6	7867.2
2021	1950.3	10140.3
Average	1785.7	8929.2

Soil Erodibility K Factor

Soil erodibility K factor was calculated using inherent soil properties following the procedure for tropical soils (El-Swaify and Dangler, 1976), which uses the percent-modified silt (0.002 - 0.1 mm), percent modified sand (0.1 - 2 mm), base saturation, percent unstable aggregates, and percent very fine sand. The calculation for measuring soil erodibility were indicated in Equation 3.

$$K = -0.03970 + 0.00311X_1 + 0.00043X_2 + 0.00185X_3 + 0.00258X_4 - 0.00823X_5 \quad \text{Eq. 3}$$

Where X_1 is the percent unstable aggregates <0.250 mm, X_2 is the product of the percent of silt (0.002-0.01 mm) and sand (0.1-2 mm) present in the sample, X_3 is the percent base saturation of the soil, X_4 is the percent silt present (0.002-0.050 mm), and X_5 is the percent sand in the soil (0.1-2 mm).

As shown in Table 3, soil erodibility K factor for the soil was calculated as 0.0150Mg h MJ⁻¹ mm⁻¹ (0.1139 t acre h [hundreds of acre ft-tonf in.]⁻¹).

Table 3 Soil properties for use in calculating the RUSLE k – Factor for the Cobija soil

Fraction	Percentage
Clay (<0.002 mm)	53
Silt (0.002–0.05 mm)	34
Sand (0.05–2 mm)	2
Sand (0.1–2 mm)	8
Base saturation	55
Unstable aggregates	3
Permeability class	2

Slope Length and Steepness LS Factor

The length and steepness LS factor represents the loss of soil per unit area on any slope, corresponding to a unit plot with 22 m long and 9% slope as shown in Equation 4.

$$LS = \left(\frac{L}{22.1} \right)^m (0.065 + 0.0454.S + 0.0065S^2) \quad \text{Eq. 4}$$

Where m=0.2 for S<1%; m=0.3 for 1%≤S≤3%; m=0.4 for 3%<S<5 and m=0.5 for S ≥5%; S average slope of the land (%), and L is the slope length (m).

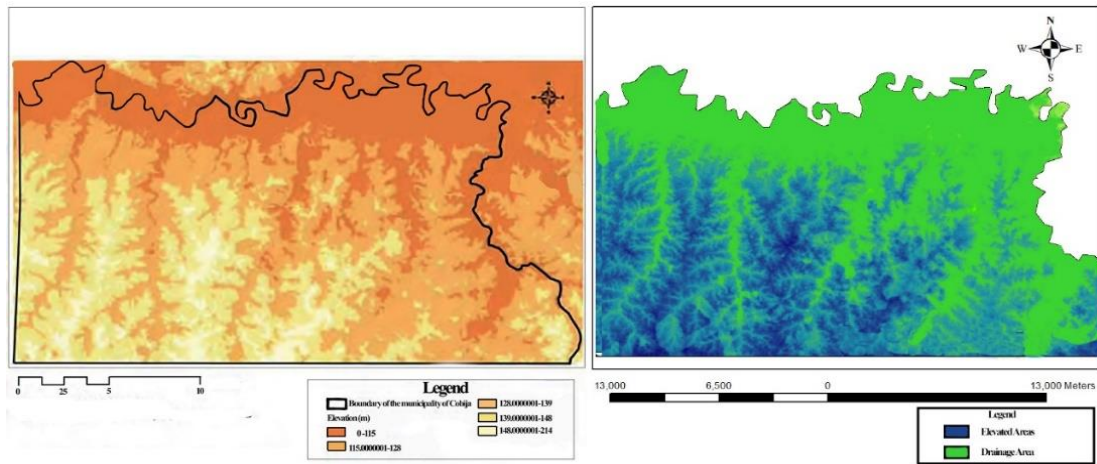


Fig. 2 Digital elevation map (DEM) in Cobija area

For determine the slope and steepness LS factor, the average slope in the drainage basin area and the average length of the slope are necessary. The result obtained for the slope and steepness LS factor was 0.5987 (Fig. 2).

Cover Management C Factor

The cover management C factor was determined from analyzed land use in the city of Cobija. The main outcomes from the observation of land use changes and the cover management C factor indicated that 66.9% deforested for timber resources, with land use change such as 20.7% for pastures to raise cattle and 12.4% for agriculture as shown in Fig. 3.

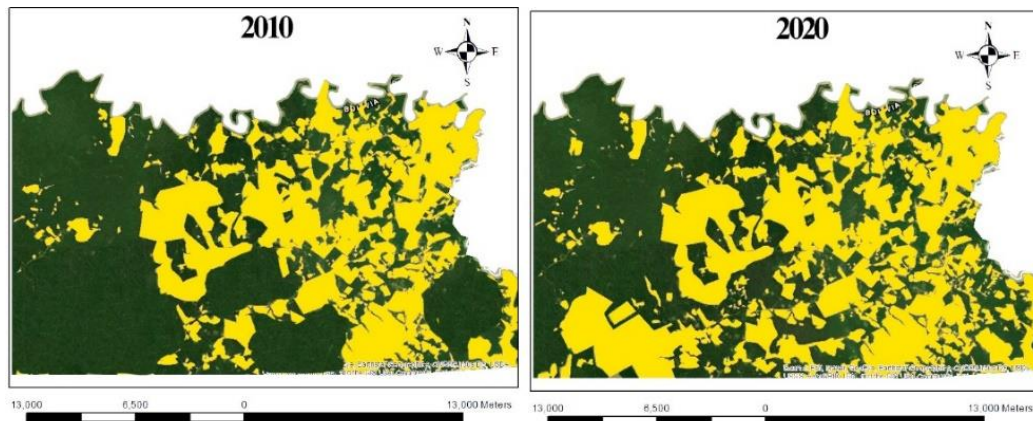


Fig. 3 Land use changes from 2010 to 2020 in the city of Cobija

Although the vegetal cover acts as a shield against the impact of the raindrop on the soil surface, this cover was lost and left the soil exposed to the impact of the raindrop. These trends increased the risk of erosion due to advancing deforestation. The observed result of the cover management C factor in the city of Cobija was 0.368.

Support Practice P Factor

For choosing the support practice P factor of conservation in the city of Cobija, the observations of satellite images and site investigation were conducted. As the results of these observations, the support practice P factor of conservation at 0.2 was decided averagely, as the soil surface was covered with permanent vegetation (Bertoni and Lombardi, 1985).

Average Annual Soil Loss in the City of Cobija

These factors were integrated into RUSLE model (Eq. 1) for obtaining the annual soil loss per unit area (A). The changes in annual soil loss in the city of Cobija from 2017 to 2021 were summarized in Table 4. The annual average was 5.902 t/ha year that was in the range of the medium soil loss from $5 < 7$ t/ha/year according to Silva (2008).

As the soil surface was covered with permanent vegetation after the deforestation, the annual soil loss per unit area (A) was in the range of the medium soil loss from $5 < 7$ t/ha/year. However, with accelerating soil erosion, soil organic matters as well as soil aggregate would be lost, and soil loss would be severer gradually. So, effective soil conservation measures should be implemented for minimizing the loss of soil organic matters as well as soil aggregate.

Table 4 Changes in annual soil loss in the city of Cobija from 2017 to 2021

Year	A (t/ha year)
2017	5.984
2018	5.258
2019	6.364
2020	5.200
2021	6.702
Total	5.902

CONCLUSION

Soil erosion by water is a serious global problem, especially in Amazonia. This study was conducted to evaluate soil losses by precipitation and runoff in the city of Cobija, Bolivian Amazonia with the RUSLE model. Although the topography showed relatively flat relief, the soil type has medium erodibility and the support practice of conservation was maintaining strands of permanent vegetation. So, the annual soil loss per unit area (A) was in the range of the medium soil loss from $5 < 7$ t/ha/year.

In the city of Cobija, Bolivian Amazonia, intense deforestation has been advanced. With accelerating soil erosion, soil organic matters as well as soil aggregate have been lost, and soil loss would be severer gradually. So, effective soil conservation measures should be implemented for minimizing the loss of soil organic matters as well as soil aggregate.

ACKNOWLEDGMENTS

We like to express special gratitude to research fellows in the Laboratory of Land and Water Use Engineering, Tokyo University of Agriculture for meaningful discussion always.

REFERENCES

- Amundson, R., Berhe, A.A., Hopmans, J.W., Olson, C., Sztein, A.E. and Sparks, D.L. 2015. Soil science, Soil and human security in the 21st century. *Science*, 348 (6235), Retrieved from DOI <https://www.science.org/doi/10.1126/science.1261071>
- Bertoni, J. and Lombardi Neto, F. 1985. *Conservação do solo*. Piracicaba-SP, 392, Retrieved from <https://www.passeidireto.com/arquivo/21438632/conservacao-de-solo/12>
- Boggs, G., Devonport, C., Evans, K. and Puig, P. 2001. GIS-based rapid assessment of erosion risk in a small catchment in the wet/dry tropics of Australia. *Land Degradation and Development*, 12 (5), 417-434, Retrieved from DOI <https://doi.org/10.1002/ldr.457>
- Da Silva, A.M., Schulz, H.E. and De Camargo, P.B. 2007. *Erosão e hidrossedimentologia em bacias hidrográficas, Segunda edição, Revista e ampliada*. RiMa, ISBN 978-85-7656099-9, Brasil.
- Hickey, R. 2000. Slope angle and slope length solutions for GIS. *Cartography*, 29 (1), 1-8, Retrieved from DOI <https://doi.org/10.1080/00690805.2000.9714334>
- Keesstra, S.D., Bouma, J., Wallinga, J., Tiftonell, P., Smith, P., Cerdà, A., Montanarella, L., Quinton, J.N., Pachepsky, Y., van der Putten, W.H., Bardgett, R.D., Moolenaar, S., Mol, G., Jansen, B. and Fresco, L.O. 2016. The significance of soils and soil science towards realization of the United Nations sustainable development goals. *Soil*, 2 (2), 111-128, Retrieved from DOI <https://doi.org/10.5194/soil-2-111-2016>
- Millward, A.A. and Mersey, J.E. 1999. Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. *Catena*, 38 (2), 109-129, Retrieved from DOI [https://doi.org/10.1016/S0341-8162\(99\)00067-3](https://doi.org/10.1016/S0341-8162(99)00067-3)
- Renard, K.G., Foster, G.R., Weesies, G.A. and Porter, J.P. 1991. RUSLE, Revised universal soil equation. *Journal of Soil and Water Conservation*, 46 (1), 30-33, Retrieved from <https://www.jsowonline.org/content/46/1/30>
- Renard, K.G. and Fremund, J.R. 1994. Using monthly precipitation data to estimate the R-factor in the revised USLE. *Journal of Hydrology*, 157 (1-4), 287-306, Retrieved from DOI [http://dx.doi.org/10.1016/0022-1694\(94\)90110-4](http://dx.doi.org/10.1016/0022-1694(94)90110-4)
- Wischmeier, W.H. and Smith, D.D. 1978. *Predicting rainfall erosion losses, A guide to conservation planning*. U.S. Department of Agriculture, Washington, USA.



Effect of Adding Agricultural and Organic Lime on Soil Properties and Survival Rate of Pathogenic Bacteria (Coliform and *E. coli*) in Farmland Soils of Kampong Cham Province, Cambodia

MUY LEANG KIM

Graduate School of Agriculture, Tokyo University of Agriculture, Japan
Email: muyleangkim70@gmail.com

MACHITO MIHARA*

Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan/
Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

Received 30 January 2022 Accepted 4 July 2022 (*Corresponding Author)

Abstract Cow manure and compost has been applied as fertilizer for many years by farmers in Kampong Cham province. Improperly processed of cow manure and compost may contained pathogenic bacteria such coliform and *E. coli* that are harmful to humans. Pathogenic bacteria coliform and *E. coli* are both recognized as hazardous microorganism in the environment and for public health. It is an important pathogen associated with several foodborne and waterborne outbreaks of gastrointestinal illness, which has been widely reported in Cambodia. Also, coliform and *E. coli* was detected in farmlands soils of Samraong and Baray Communes, Kampong Cham Province. The contamination of agricultural land, surface water, irrigation water, and fresh vegetables, can become a reservoir of infections. Therefore, it is necessary to eliminate the pathogenic bacteria from the contaminated areas. Many studies have shown that inactivation of pathogens in biosolids depends on several factors, from that the soil pH is one of the dominant factors affecting the inactivation of pathogenic bacteria. Increasing of pH can be achieved by adding agricultural limestone calcium carbonate (CaCO_3) or quick lime (CaO). The objectives of this study are to investigate and evaluate the effects of adding different agricultural and organic lime materials on soil chemical properties and the survival rates of pathogenic bacteria coliform and *E. coli*. Pot experiments was conducted and different CaCO_3 and CaO material such CaCO_3 powder, eggshell, clamshell, and wood ash are used for the soil amendment. The CaCO_3 and CaO added to soil at the ratio of 0 g, 5 g, and 15 g to 750 g of soil to each pot. The CaO obtained by burning the CaCO_3 powder, eggshell, clamshell, and wood ash at 800°C . Soil chemical and biological parameters such as pH, EC, K^+ , Na^+ , Ca^{2+} , coliform and *E. coli* were determined. The results showed that increase in soil pH due to lime addition were observed. However, there's no significant difference of soil pH responding to amounts of lime added 5 g, 10 g and 15 g. Similar trends were also observed between the unburned and burned lime material. The survival rate of coliform and *E. coli* were decreased with unburned and burned lime added, the pathogenic bacteria can be eliminated at 7 days after addition of lime. Since the performance of unburned and burned lime on the survival rates of pathogenic bacteria no different. So, it is not necessary to burn the lime material of CaCO_3 , eggshell, clamshell, and wood ash. As burning material need the temperature at 800°C , farmers need a burner machine that can reach to that temperature. Farmers in Cambodia usually burning wood or charco to get the heat. Therefore, it is recommended that farmers can use the unburned lime instead of burned materials in Kampong Cham Province.

Keywords: agricultural lime, calcium carbonate, fertilizers, shells, soil pH, microorganisms

INTRODUCTION

Organic amendments or fertilizers including livestock manure and compost are valuable sources of nutrients for plant's growth. The organic matter also contributing to improve the soil quality and fertility. Application of organic waste products to agricultural land without control of their hygienic safety is one of the potential risks by which pathogens may enter the human food chain (Nicholson et al., 2005). Pathogenic bacteria in raw vegetables and their consumption affects human health, resulting in diarrhea or serious disease (Beuchat, 1996; Summer and Peters, 1997). Muyleang and Mihara (2019) reported that the coliform and *E. coli* was found in farmland soils in Samraong and Baray Commune, Prey Chhor District, Kampong Cham Province. The occurrence of coliform and *E. coli* maybe a potential of food-borne pathogens in the farmlands soils as well as vegetable. Also, the application of fresh cow manure or immature compost that contained pathogenic bacteria can spread the pathogens to the farmland's soils. The contamination of agricultural lands, surface water, irrigation water, and fresh vegetable can become a reservoir of infection. To produce safety agricultural production, it is necessary to eliminate pathogenic bacteria such as coliform and *E. coli* in farmlands. The inactivation of pathogens in biosolids depends on several factors such as temperature, moisture content, competition from indigenous microflora, soil types and texture (Martin et al., 1990; Ward et al., 1981; Russ and Yanko, 1981). However, the survival rate of *E. coli* became remarkably low with pH higher than 9.0. Increasing of pH can be achieved by adding of agricultural lime (CaCO_3) and quick lime (CaO). Lime is commonly used to farmlands soil for neutralizing soil acidity for centuries and has been demonstrated to improve crop yield (Acosta et al., 2000). Calcium carbonate (CaCO_3) is one of the basic inorganic and inexpensive materials that were applied in agriculture industries to stabilize the soil pH. About 95% of CaCO_3 can be obtained from shellfish and the rest is organic matter and other compounds (Hamester et al., 2012). An increase in soil pH, with liming application help to increase in microbial activity, resulting in increased decomposition of soil organic matter. Therefore, the study was proposed different lime material application and its effect on soil properties and the microbial survival rates.

OBJECTIVE

The objectives of this study are to investigate and evaluate the effects of adding different agricultural and organic lime materials on soil chemical properties and the survival rates of pathogenic bacteria coliform and *E. coli*.

METHODOLOGY

Experimental Designed and Materials Used

Pot experiment was conducted in the experimental room at Tokyo University of Agriculture from August to September 2021 during summer season. Fresh cow dungs were collected from Onoji Farm and added to soil samples to get pathogenic bacteria contamination in Fig. 2.

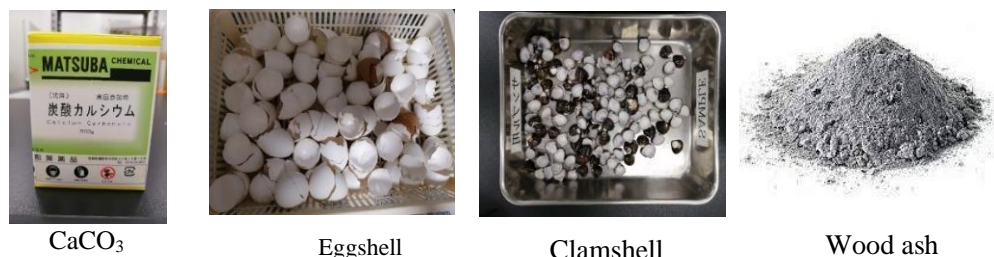


Fig. 1 Agricultural and organic lime materials

Unburned and burned lime materials were used for the experiment. The unburned lime materials such Agricultural lime CaCO_3 powder, organic lime such eggshell, clamshell, and wood ash (Fig. 1), and the burned lime materials were obtained from burned of CaCO_3 , eggshell, clamshell, and wood ash at 800°C .



Fig. 2 Cow manure collection in Onoji Farm, Tokyo, Japan (left) and pot experiment design (right)

The pH of the soil samples used for the experiment was around 6.8 to 6.9. The amounts of lime materials were added from 5 g, 10 g, and 15 g to 750 g of soil, this amount added in the experiments (Fig. 3) was decided based on practical use in Cambodia (Chakraborty, 2014). For the actual field of lime added was from 33 kg a^{-1} , 66 kg a^{-1} , and 99 kg a^{-1} .

Chemical Properties of Lime Materials Used

The lime materials of CaCO_3 , eggshell, clamshell, and wood ash that used for the experiment has the calcium carbonate content (CCC%) of 99.9%, 97.8%, 98.4% and 40% respectively. The pH of each material ranged from 9.5 to 9.9 (Table 1).

Table 1 Chemical properties of lime materials used in the experiments

Lime materials	Calcium carbonate content (%)	pH	EC (mS/cm)	Ca^{2+} (mg/L)
CaCO_3	98.9	9.5	0.45	23
Eggshell	97.8	9.5	0.26	20
Clamshell	98.4	9.5	1.03	14
Wood ash	40	9.9	14.6	170

Samples Preparation

- Soil samples from Samraong and Baray Communes were used for the experimental. The samples were mixed and sieved with 2 mm sieve to remove the leaves, root and stone, and air dried at room temperature before used for the experiment. The initial soil physical, chemical, and biological properties were analyzed.
- Eggshell and clamshell were collected from daily consumption in Cambodia, all the eggshell and clamshell were washed and air dried before crushed to powder. For CaCO_3 and wood ash were obtained from the commercial products. Also, for the CaO that was used for the experiment was obtained from burned of the raw materials of CaCO_3 , eggshell, clamshell, and wood ash at 800°C .

Treatments	Unburned	Burned	Mass of lime (g)
T0 (Control)	600 g (soil) + 150 g (cow manure)	600 g (soil) + 150 g (cow manure)	0
T1-1	Soil + cow manure + CaCO₃ powder	Soil + cow manure + CaO powder	5
T1-2			10
T1-3			15
T2-1	Soil + cow manure+ Eggshell	Soil + cow manure+ Eggshell	5
T2-2			10
T2-3			15
T3-1	Soil + cow manure+ Clamshell	Soil + cow manure+ Clamshell	5
T3-2			10
T3-3			15
T4-1	Soil + cow manure+ Wood ash	Soil + cow manure+ Wood ash	5
T4-2			10
T4-3			15

Fig. 3 The experimental design of lime materials added treatments

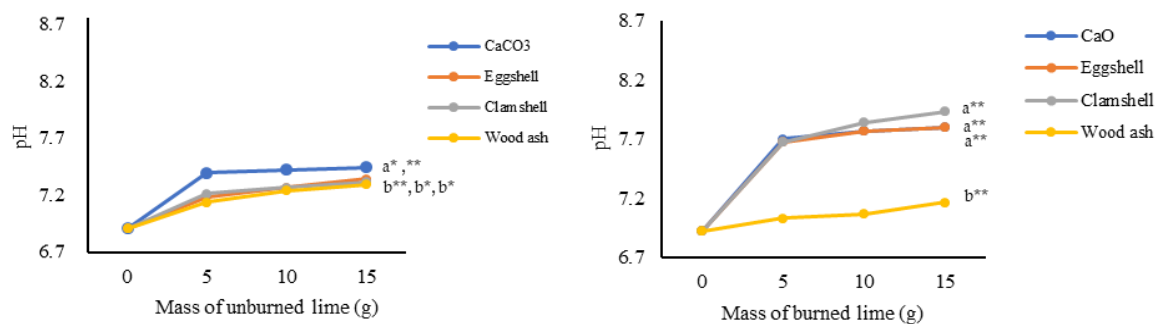
Data Collection and Analysis

The soil samples were collection from the first day before and after added of different lime materials and the following collection were done in every two days. The samples were analyzed on the soil water contents, soil pH, EC, K⁺, Na⁺, Ca²⁺, coliform and *E. coli*. T-test was used to see the significant difference between the variables.

RESULTS AND DISCUSSION

Effect of Unburned and Burned Lime Materials on Soil Chemical Properties

Increases in soil pH due to lime addition were observed in this study. Similar tends of soil pH increased were observed between the unburned lime (CaCO₃) and burned lime (CaO) materials in (Fig. 4).

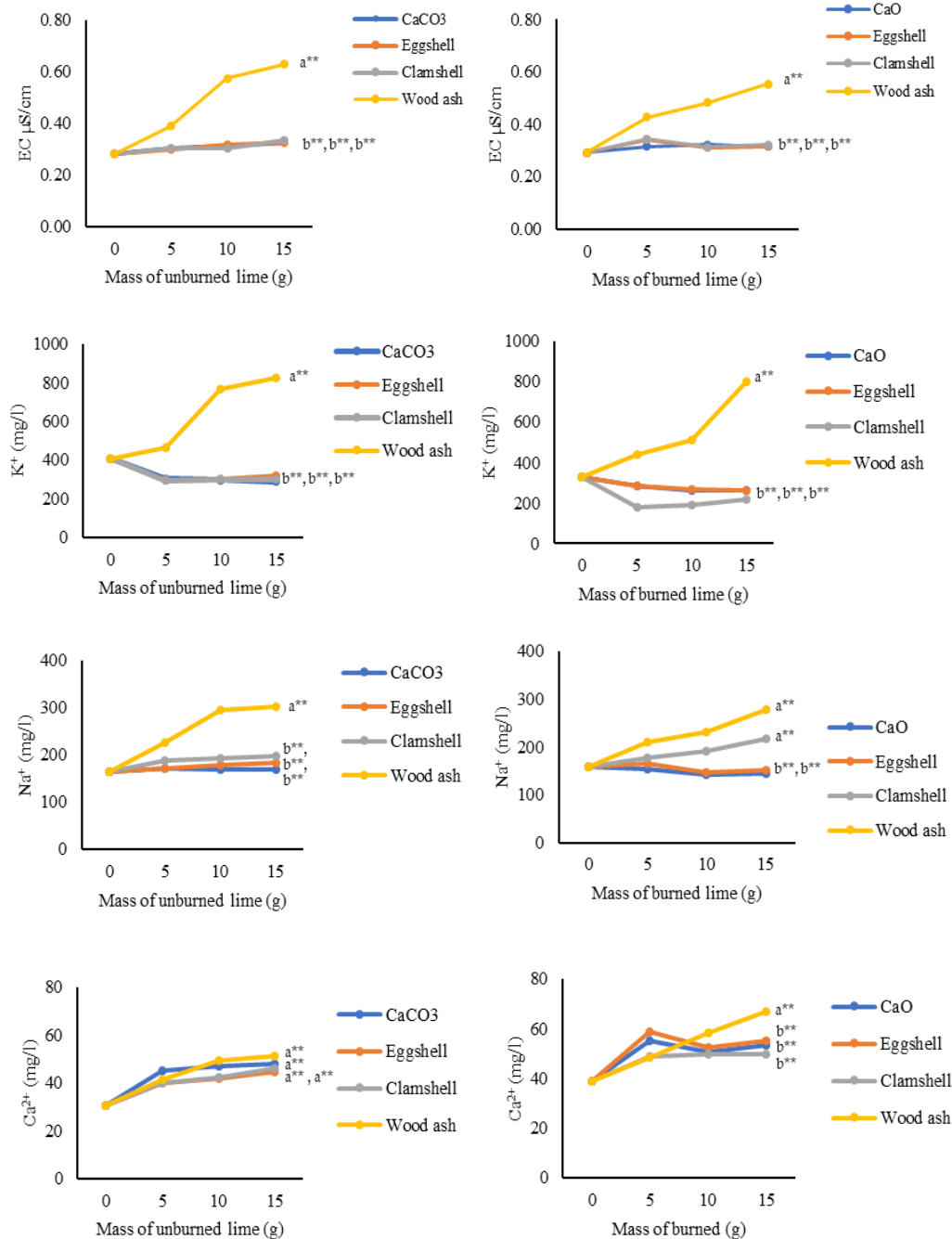


*: Significance difference at 95%, $p < 0.05$, **: $p < 0.01$

Fig. 4 The effect of unburned and burned lime materials on soil pH

Addition of CaCO₃, the calcium ions (Ca²⁺) from the lime adsorb on soil particle surface and then the carbonate (CO₃) take place and reacts with the acidity to form water and carbon dioxide. However, the effect of wood ash on soil pH became lower due to losses of K₂O after burning at 800° C. Moreover, the CaO materials provided more effectiveness to increase soil pH than CaCO₃ materials, except the burned wood ash which losses of K₂O. Burned lime (CaO) reacts with water to form calcium hydroxide (Ca (OH)₂) and the solubility is higher than of CaCO₃. The wood ash

without extra burning should be applied to the farmlands directly. There was no significant difference of soil pH responding to the amounts of lime added in this study. Therefore, the amounts of lime added less than 5 g should be considered.



** : Significance difference at 99%, $p < 0.01$

Fig. 5 The effect of unburned and burned lime materials on soil EC, K⁺, Na⁺, and Ca²⁺

All the treatment with unburned and burned lime material application generally increased the soil EC, K⁺, Na⁺, and Ca²⁺ when compared with control. However, the application of wood ash increasing the soil EC higher than other unburned and burned lime treatments (Fig. 5). Increased in EC was associated with increased concentration of K⁺, Na⁺ and Ca²⁺ in CaCO₃, eggshell, clamshell, and wood ash treatment. Similar trend was also found in the burned lime treatments, the soil EC

was also slightly increase with burned lime application (Fig. 5). Additionally, increased of wood ash rates significantly effect to increase of soil EC compared to other lime treatment.

Wood ash and burned wood ash shown significantly increased higher of soil cation such as K^+ , Na^+ and Ca^{2+} with increasing rates of wood ash application while other treatment the change of application rate with the increasing of nutrients was not significantly different. Increase in K^+ , Na^+ and Ca^{2+} reflected to the supply of these elements by wood ash and the high solubility of wood ash one applied to the soil. It was observed that the unburned lime such $CaCO_3$, eggshell, clamshell, wood ash and burned CaO , eggshell, clamshell, wood ash effects the soil solution chemistry in two ways, all the material ack as liming agent and as a supplier of nutrients. There is evidence that the limes application and wood ash could represent increased in availability of nutrients for plants. However, large concentration of basic cations obtained with higher application rates could be a concern because of potential solute transport to surface water and ground water. For maximum effectiveness, limes should be uniformly spread and incorporated into the soil. However, farmers in Cambodia tend to spread the lime by hands is therefore high laborious is need. Therefore, lime application from $CaCO_3$, eggshell, clamshell, and wood ash must be applied at the reasonable rates to avoid any risk for the environment, soil quality and farmers laborious.

Effect of Unburned and Burned Lime Materials on Survival Rate of Coliform and *E. coli*

The survival rate of coliform decreased due to lime materials. Lime increased the soil pH, reducing the survival rate of coliform, even the pH of soil didn't reach to 9.0 (less than 8.0). Pathogenic bacteria were eliminated at 7 days after the addition of lime materials (Fig. 6). However, the burned wood ash had low potential in eliminating coliform compared with other materials as its low increases in soi pH compared to other lime materials. Also, there is no significant difference of survival rate of coliform to the amounts of lime added. So, the amounts of less than 5 g or 33 kg a^{-1} should be considered. Similar trends of CaO used were also observed compared with $CaCO_3$ materials. Beside that the CaO from the burned material of $CaCO_3$ working well on eliminating the pathogenic bacteria compared to other burned materials. Increase in soil pH, EC, and concentrations of elements such K, Ca and Na have been shown to be main driver in shaping the bacterial communities in various soils. Both burned and unburned lime materials could eliminate *E. coli* in 7 days. Therefore, farmers can apply lime materials directly without burning.

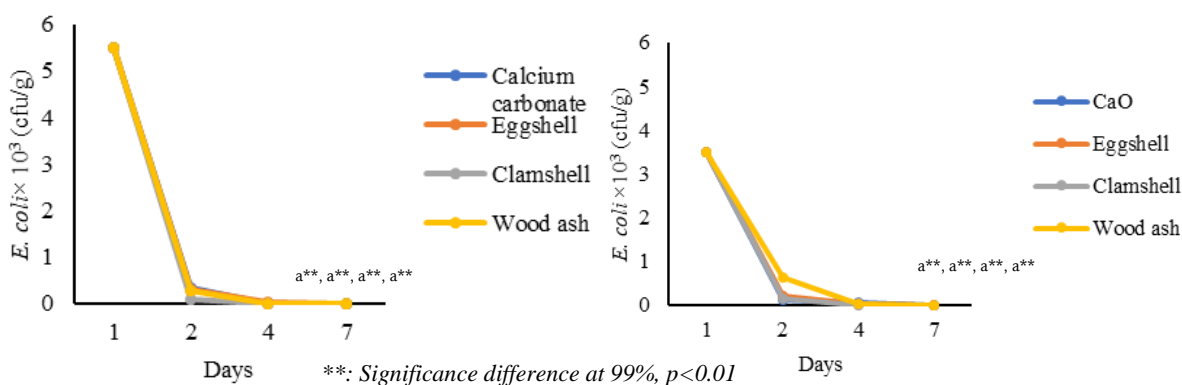


Fig. 6 The effect of unburned and burned lime materials on the survival rates of *E. coli*

CONCLUSION

Different lime materials application increased soil pH, EC, K^+ , Na^+ , and Ca^{2+} . Similar trends were observed on burned lime material. CaO materials has more effective to increase soil pH than $CaCO_3$ materials, however, the effect of burned wood ash on soil pH became lower due to losses of K_2O after burning at $800^\circ C$. The wood ash without extra burning should be applied to the farmlands directly. There was no significant difference of soil pH responding to the amounts of lime added in this study. However, Wood ash and burned wood ash shown significantly increased higher of soil

cation such as K^+ , Na^+ and Ca^{2+} than other lime treatment, increasing of wood ash application rates lead to increase of soil cation while other treatment the change of application rates has not significantly different to the increased of soil cation. It was observed that the unburned lime such $CaCO_3$, eggshell, clamshell, wood ash and burned CaO , eggshell, clamshell, wood ash effects the soil solution chemistry in two ways, as liming agent and as a supplier of nutrients. There is evidence that the limes application and wood ash could represent increased in availability of nutrients for plants. The survival rate of coliform decreased due to lime materials addition. Pathogenic bacteria were eliminated at 7 days after the addition of lime materials. Both burned and unburned lime materials could eliminate *E. coli* in 7 days. Lime increased the soil pH, reducing the survival rate of coliform, even the pH of soil didn't reach to 9.0 (less than 8.0). Since there is no significant difference of soil pH, and the survival rates of coliform and *E. coli* to the amount of lime added, so the amounts of less 5 g of lime adding should be considered. Moreover, lime application also effects to increase the soil cation large concentration of basic cations obtained with higher application rates could be a concern because of potential solute transport to surface water and ground water. For maximum effectiveness, limes should be uniformly spread and incorporated into the soil.

However, farmers in Cambodia spread the lime by hands is therefore needed high laborious. Therefore, lime application from $CaCO_3$, eggshell, clamshell, and wood ash must be applied at the reasonable rates to avoid any risk for the environment as well as to avoid the labor shortage. Also, farmers in Cambodia usually burning wood or charco to get the heat. To avoid extra laborious, it is recommended that farmers can use the unburned lime instead of burned materials in Kampong Cham Province. Inconclusion increases in soil pH, EC, K^+ , Na^{2+} , and Ca^{2+} by adding of $CaCO_3$, eggshell, clamshell and wood ash can eliminate pathogenic bacteria effectively within 7 days, therefore, farmers can directly use eggshell, clamshell, and wood ash without burning for eliminating pathogenic bacteria in the farmland's soils. Additionally, local farmers should be trained on production and application of these lime materials.

REFERENCE

- Anderson, N.P., Hart, J.M., Sullivan, N.M., Christensen, N.W., Horneck, D.A. and Pirelli, G.J. 2013. Applying lime to raise soil pH for crop production (Western Oregon). Oregon State University Extension Service, EM9057, Retrieved from <https://catalog.extension.oregonstate.edu/em9057>
- Beuchat, L.R. 1996. Pathogenic microorganisms associated with fresh produce. *Journal of Food Protection*, 59 (2), 204-216, Retrieved from DOI <https://doi.org/10.4315/0362-028X-59.2.204>
- Chakraborty, I., Capito, M., Jacks, C. and Pringle, R. 2014. Household-level application of hydrated lime for on-site treatment and agricultural use of latrine sludge. 37th WEDC International Conference, Hanoi, Vietnam. Briefing Paper, Retrieved from <https://www.fsmttoolbox.com/assets/pdf/109.pdf>
- Demeyer, A., Voundi Nkana, J.C. and Verloo, M.G. 2001. Characteristics of wood ash and influence on soil properties and nutrient uptake, An overview. *Bioresource Technology*, 77 (3), 287-295, Retrieved from DOI [https://doi.org/10.1016/S0960-8524\(00\)00043-2](https://doi.org/10.1016/S0960-8524(00)00043-2)
- Hamester, M.R.R., Balzer, P.S. and Becker, D. 2012. Characterization of calcium carbonate obtained from oyster and mussel shells and incorporation in polypropylene. *Materials Research* 15 (2), 204-208, Retrieved from DOI <https://doi.org/10.1590/S1516-14392012005000014>
- Martin, J.H. Jr., Bostain, H.E. and Stern, G. 1990. Reduction of enteric microorganisms during aerobic sludge digestion. *Water Research*, 24 (11), 1377-1385, Retrieved from DOI [https://doi.org/10.1016/0043-1354\(90\)90157-2](https://doi.org/10.1016/0043-1354(90)90157-2)
- Muyleang, K. and Mihara, M. 2019. Effect of fertilization on soil microorganisms in Kampong Cham Province, Cambodia. *International Journal of Environmental and Rural Development*, 10 (1), 40-46, Retrieved from DOI https://doi.org/10.32115/ijerd.10.1_40
- Nicholson, F.A., Groves, S.J. and Chambers, B.J. 2005. Pathogen survival during livestock manure storage and following land application. *Bioresource Technology*, 96 (2), 135-143, Retrieved from DOI <https://doi.org/10.1016/j.biortech.2004.02.030>
- Ohno, T. and Erich, M.S. 1990. Effect of wood ash application on soil pH and soil test nutrient levels. *Agriculture, Ecosystems and Environment*, 32 (3-4), 223-239, Retrieved from DOI [https://doi.org/10.1016/0167-8809\(90\)90162-7](https://doi.org/10.1016/0167-8809(90)90162-7)

- Summer, S.S. and Peters, D.L. 1997. Microbiology of vegetables. In Smith, D.S. (Ed.), Processing Vegetables, Science and Technology, 87-106, Technomic Publishing Co. Inc., Lancaster, USA.
- Ward, R.L., Yeager, J.G. and Ashley, C.S. 1981. Response of bacteria in wastewater sludge to moisture loss by evaporation and effect of moisture content on bacterial inactivation by ionizing radiation. *Applied Environmental Microbiology*, 41 (5), 1123-1127, Retrieved from DOI <https://doi.org/10.1128/aem.41.5.1123-1127.1981>
- Yanko, W.A. 1988. Occurrence of pathogens in distribution and marketing municipal sludges. Final Report, Project CR-81589. U.S. Environmental Protection Agency, Washington D.C., USA.



Product Formulation from a By-Product from the Production of Coconut - Based Food Delicacies

MARIA DONNA F. BUATES*

*Bohol Island State University, Main Campus, Tagbilaran City, Philippines
Email: mariadonna.buates@bisu.edu.ph*

CHONA C. FULLIDO

Bohol Island State University, Main Campus, Tagbilaran City, Philippines

Received 21 February 2022 Accepted 4 July 2022 (*Corresponding Author)

Abstract This study aims to create healthy food products thus economical since it utilizes a so-called “scrap” of coconut as a main ingredient. Coconut residue may be considered as residual but studies shows that it contains health-affirming benefits. The coconut residue gathered from the local delicacy vendors are submitted to the DOST Laboratory for microanalysis to test if it is safe for production. Consequently, it contains the following result: aerobic plate count- 2.5×10^6 cfu/g, total coliform count - 3.7×10^3 cfu/g, E. coli count - $< 1.0 \times 10$ cfu/g, enumeration of S. aureus - 9.0×10 cfu/g, salmonella detection – negative, mold and yeast count - 2.5×10^5 cfu/g. The report of microanalysis reflects that the coconut residue collected from the rice cake vendors is not safe to be processed. Thus, the coconut residue utilized in this study is firsthand gathered by the researcher with the observance of utmost food safety to avoid from microorganism. For the sensory attributes, the color got the highest numerical rating of 8.66 described as “like extremely”, while the rest of the attributes are at the range of “like very much”. The texture got the average weighted mean of 7.5, for the aroma, 7.74, for the taste, 7.56 and for the general acceptability 7.72. This result indicates that the coco nuggets is generally acceptable to the consumers, however, 34 or 68% of the participants suggested that the coco nuggets is best served with a dipping. For the nutritional content, coco nuggets contain the vital nutrients like protein, carbohydrates, dietary fiber, calcium and potassium.

Keywords coconut residue, coco nuggets, microanalysis, nutritional content

INTRODUCTION

The Philippines is a tropical country where growing the most versatile crop can be easily cultivated. Coconut *Cocos nucifera* is known as the tree of life all of its parts have a function. It has been part of Filipino cuisine and became the staple ingredient for some Filipino delicacies. It is also believed as a “functional food” since it provides many health benefits beyond its nutritional content.

The endosperm consists of liquid and solid portions. The liquid endosperm is in high demand as a freshwater or sports beverage product attributed to isotonic properties due to its mineral, sugar, and vitamin contents (Prades et al., 2016). The solid endosperm forms a white layer lining in the inside of the shell, and when it is extracted from mature coconut and dried, it is known as copra, which is commonly used as a source of coconut oil (Patil et al., 2017). When extracted from young fruit, the solid endosperm is gelatinous, a consistency that makes it useful in producing desserts or as a food supplement. No matter if it is grown and/or processed on artisanal or industrial scales, the coconut fruit is a vital income source for coconut growers in producing countries (Angeles et al., 2018).

The health-affirming characteristics of the coconut have become widely known over the past 10 years, and the spread of coconut-inspired health foods looks set to continue. As well as being a great addition to almost any diet, the coconut is also renowned for its versatility and the many

different foods that can be created from it. (Richards, 2017). In addition, Coconut meat has some nutrients including proteins, fats, carbohydrates, calcium, phosphorous, iron, ascorbic acid, and water (Sinaga et al., 2015). However, many people prefer this coconut residue which is considered as “leftover” because it does not contain any gluten or grains, making it ideal for those with a digestive problem or gluten intolerance. It is also rich in fiber and protein.

This study introduces coconut residue as the main ingredient in a food item. This may be considered as residual but studies show that it contains health-affirming benefits. Related studies on coconut residue are hardly available but nevertheless, coconut flour will be presented as there is a slight difference, especially in the process. The only difference is that it does not undergo the grinding and pulverizing process.

Coconut flour has 5 grams of fiber per tablespoon, which is significantly more than whole-grain flour's 0.8 grams or white flour's 0.2 grams of this indigestible carbohydrate. A large portion of this fiber is the insoluble variety, which gives your stool more weight, makes you feel fuller, prevents constipation, and improves colon health. Make smoothies, sauces, or baked products with coconut flour to help you consume the daily recommended 25 to 38 grams of fiber (Boldt, 2011).

Dietary fiber can be classified into insoluble dietary fiber and soluble dietary fiber. Soluble dietary fiber (SDF) could fully hydrolyze in the colon, promote the growth of intestinal probiotics, and inhibit lipid transport, cardiovascular disease, and scavenge free radicals (Huang et al., 2015). The composition of SDF is an essential index for the quality of dietary fiber. SDF is composed of carbohydrate-based polymers, including pectic substances, gums, mucilage, and some hemicelluloses, which significantly benefit human health; it can prevent heart disease, obesity, and cancers (Du et al., 2019).

For those with and without diabetes, fiber is an essential nutritional component. Despite being a form of carbohydrate, fiber doesn't cause blood sugar to rise. In contrast to other types of carbohydrates, fiber does not affect blood sugar levels in the same way since it is not digested by your body. Soluble and insoluble fibers are mixed together in foods. The first kind turns into a gel after dissolving in water and aids in slowing glucose absorption. Soluble fiber-rich diets may help lower blood sugar levels. The other form of fiber increases stool volume, encouraging regularity, rather than dissolving in water (Renee, 2017).

When compared to conventional grain flours, coconut flour has a significantly lower carbohydrate content. The proximate analysis of coconut flour per 100 g sample is as follows: moisture, 3.6%; ash, 3.1%; fat, 10.9%, protein, 12.1%; and carbohydrates 70.3%. Coconut flour contained 60.9% total dietary fiber, 56.8% insoluble and 3.8% soluble. Table 1 shows the short chain fatty acids produced from dietary fiber fermentation of fiber isolates of coconut flour. The dietary fiber from coconut flour was fermentable and produced short chain fatty acids with butyrate > acetate > propionate (Trinidad et al., 2006)

Coconut flour indicated higher levels of protein, ash, fibre, and fat compared to wheat flour. Coconut meal defatting has the potential of increasing its protein content because the crude fat and soluble carbohydrates were removed in the extraction process (Makinde and Eyitayo, 2019).

A serving of food's total amount of carbohydrates should be taken into account, but it's also crucial to examine the type of carbohydrates you consume. The glycemic index makes predictions about how food's carbohydrate content will affect your blood sugar levels. Low glycemic index foods help stabilize blood sugar levels, which helps you lose weight and prevent chronic diseases at the same time. High glycemic index foods cause significant swings in your blood sugar levels. According to a 2003 article in the "British Journal of Nutrition", foods with a higher percentage of coconut flour had a lower glycemic index, making them healthier carbohydrate options (Jacob, 2017).

Another advantage of using the grated coconut leftover is that an ample quantity will be obtained in view of the fact that Bohol is producing a native sticky sweet delicacy locally known as “kalamay” which coconut milk is one of the main ingredients. After extracting the coconut milk, as per the knowledge of the researcher, the coconut residue is typically thrown or used as livestock feed.

In view of the above idea of introducing a coco-nuggets recipe, it does not only satisfy the taste buds and hunger but also may also give nutritional content. Hence, the researcher finds this study a worthwhile undertaking.

OBJECTIVE

The main thrust of this study is to develop a value-added food product by utilizing leftover materials from the production of coconut-based food delicacies.

METHODOLOGY

Collecting of Coconut Residue

Food safety is the most taken importance. Therefore, right after extracting the coconut milk, the collected coconut residue was placed in a zip lock packaging and immediately submitted to the Department of Science and Technology Regional Standards and Testing Laboratory to examine if the coconut residue is safe to be used.

Recipe Formulation

The ingredients used in this study were summarized in Table 1.

Table 1 Ingredients used in this study

Description	Quantity	Unit
Garlic, minced	15	grams
Onion, minced	42	grams
White pepper, ground	5	grams
Salt, fine	15	grams
Eggs, large	200	grams
All-purpose flour	155	grams
Coconut residue, slightly dehydrated	220	grams

Ingredients and quantities are formulated by multiple trials.

Preparation

The coconut residue was prepared using a food processor to ensure dry residue. The ingredients were measured accurately using a weighing scale then mixed well. The mixture was then molded into a flat circle shape and weighed to 10 grams to ensure uniform size. Then, the molded mixture was deep-fried until golden brown.

Evaluating of Sensory Characteristics

In this evaluation for acceptability, fifty participants from were randomly selected. It is composed of eight food technology instructors, thirty-five food technology students, and seven housewives. The participants were presented with the coco-nuggets and were asked to indicate their degree of preference through a 9-point hedonic scale anchored by “dislike extremely” and “like extremely”. The food tasting was done between 2:00 to 3:00 PM because according to Edelman, S. 2014, in his book on sensory evaluation, panelists should not ingest any food 1 hour before food tasting and it is considered the best time of the day that the panelists are not overly hungry or full that can possibly affect their rating.

Nutritional Analysis

To determine the nutrient content of the coco nuggets, the product was subjected to nutrition analysis at the Department of Science and Technology Regional Standards and Testing Laboratory. As recommended by the laboratory personnel, a total of 250 grams were submitted in a plastic stand-up pouch.

RESULTS AND DISCUSSION

To comply with the Republic Act No. 10611, an act to strengthen the food safety regulatory system in the country to protect consumer health and facilitate market access of local foods and food products, and for other purposes, the coconut residue collected from the vendors of local delicacy with coconut milk was submitted to a microbiology analysis at the DOST Laboratory to determine if it is safe for production.

Table 2 Report of micro analysis of the fresh coconut residue

Parameter	Results
Aerobic plate count	2.5×10^6 cfu/g
Total coliform count	3.7×10^3 cfu/g
E. coli count	$< 1.0 \times 10$ cfu/g
Enumeration of S. aureus	9.0×10 cfu/g
Salmonella detection	negative
Mold and yeast count	2.5×10^5 cfu/g

According to the Philippine National Standards – Bureau of Agricultural and Fisheries Product Standards 25:2007, the microbial count shall not exceed the following limits: salmonella – negative, total plate count – 5,000 cfu/gram, coliform count – 50 cfu/gram, yeast 100 cfu/gram, molds 100 cfu/gram, *E. coli* - < 3 mpn/gram. Furthermore, according to Microbial Guidelines for Food revised 2014, *Staphylococcus aureus*, the limit is 10,000 cfu/gram. Therefore, the report of microanalysis in table 1 reflects that the coconut residue collected from the delicacy vendors is not safe to be processed. Thus, the coconut residue utilized in this study is firsthand gathered by the researcher with the observance of utmost food safety to avoid microorganisms.

Table 3 Sensory evaluation result of the coco nuggets

N=50

Sensory Attributes	Rating (Mean)	Description	Standard Deviation
Color	8.66	Like Extremely	0.593
Texture	7.5	Like Very Much	1.129
Aroma	7.74	Like Very Much	0.922
Taste	7.56	Like Very Much	1.146
General Acceptability	7.72	Like Very Much	0.927

Table 3 reflects the sensory attributes of the coco nuggets. The color got the highest numerical rating of 8.66 described as “like extremely”, while the rest of the attributes are at the range of “like very much”. The texture got the average weighted mean of 7.5, for the aroma, 7.74, for the taste, 7.56, and for the general acceptability 7.72. This result indicates that the coco nuggets are generally acceptable to the consumers, however reflected in the comment section of the questionnaire, 34 or 68% of the participants suggested that the coco nuggets are best served with a sauce or dipping.

Food has to be analyzed or tested because the knowledge of the chemical composition is important to the health, well-being, and safety of consumers. (Nollet, 2015). The nutrition facts panel on food packages was designed to provide comprehensible quantitative nutrition information that would allow consumers to make more informed food choices that could result in significant long-term health benefits (Burton et al., 1999).

Table 4 shows the computation of nutrition facts of the coco nuggets examined by the Department of Science and Technology Regional Office No. 7 - Regional Standards and Testing Laboratory (DOST-RSTL).

Table 4 Nutrition information / facts / declaration

Nutrition facts	
9 servings per container	
Serving size	4 pieces (43 g)
Amount per serving	
Calories	140
	(% daily value*)
Total fat 2 g	3%
Sodium 560 mg	23%
Total carbohydrates 27 g	9%
Total dietary fiber 7 g	27%
Total Sugars 0 g	
Includes 0g added sugars	0%
Protein 3 g	
Calcium	2%
Potassium	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

This is based on Philippine Recommended Energy and Nutrient Intakes (RENI) for males ages nineteen (19) to twenty-nine (29). For every serving size of 4 pieces (43 grams), coco nuggets contain 140 kilocalories of energy, 2 grams of Total Fat, 560 milligrams of Sodium, 27 grams of Total carbohydrates, 7 grams of Total Dietary Fiber, and 3 grams of Protein. The coco nuggets also contain minerals like calcium and potassium. RENI's are levels of energy and nutrient intakes that are considered adequate for the maintenance of health and well-being of persons belonging to a particular age group. The figure given is a percentage of this target level.

Physiologically, potassium is the most abundant cation in the intracellular fluid, where it plays a crucial role in cell function, maintaining intracellular fluid (ICF) volume and transmembrane electrochemical gradients (Ekmekcioglu et al., 2016).

CONCLUSION

The main thrust of this paper is to introduce a new recipe that utilizes residual from coconut which has been used for processing coconut-based delicacies. This is to utilize the coconut residue out from the producer/vendor of the local delicacies that coconut milk is an ingredient. The report of the microanalysis in Table 1 reflected that the collected coconut residue from the local delicacies' vendor is not safe to be processed, so for the product formulation, the researcher collected the coconut residue firsthand to assure utmost food safety. Lectures for the producers of local delicacies and thorough implementation and monitoring on Good Manufacturing Practices (GMP) and Good Operating Practices (GOP) is highly recommended to ensure that the residual is still safe for processing, thus, meeting the purpose of this study.

REFERENCES

Angeles, J.G.C., Lado, J.P., Pascual, E.D., Cueto, C.A., Laurena, A.C. and Laude, R.P. 2018. Towards the understanding of important coconut endosperm phenotypes, Is there an epigenetic control? *Agronomy*, 8 (10), 225, Retrieved from DOI <https://doi.org/10.3390/agronomy8100225>

- Boldt, A. 2011. What are the health benefits of flour. Retrieved from <https://healthfully.com/what-are-the-health-benefits-of-coconut-flour-3438619.html>
- Bureau of Agriculture and Fisheries Standards. 2007. Philippine national standard. Desiccated Coconut, PNS/BAFPS 25: 2007, Retrieved from https://bafs.da.gov.ph/bafs_admin/admin_page/pns_file/2022-10-20-dessicated%20coconut.pdf
- Burton, S., Garretson, J.A. and Velliquette, A.M. 1999. Implications of accurate usage of nutrition facts panel information for food product evaluations and purchase intentions. *Journal of the Academy of Marketing Science*, 27 (4), 470-480, Retrieved from DOI <https://doi.org/10.1177/0092070399274006>
- Department of Health, Bureau of Food and Drugs. 2014. Guidelines for the assessment of microbiological quality of processed foods. Retrieved from <https://www.fda.gov.ph/wp-content/uploads/2021/06/FC-2014-014-Minimum-Numbers-of-Samples-Units-Required-for-Each-Test-Analysis.pdf>
- Du, X., Bai, X., Gao, W. and Jiang, Z. 2019. Properties of soluble dietary fibre from defatted coconut flour obtained through subcritical water extraction. *International Journal of Food Science and Technology*, 54 (4), 1390-1404, Retrieved from DOI <https://doi.org/10.1111/ijfs.14071>
- Edelstein, S. 2014. *Food science, An ecological approach* (2nd ed.), Jones & Bartlett Publishers, ISBN 9781284122305, Burlington, USA.
- Ekmekcioglu, C., Elmadfa, I., Meyer, A.L. and Moeslinger, T. 2016. The role of dietary potassium in hypertension and diabetes. *Journal of Physiology and Biochemistry*, 72, 93-106, Retrieved from DOI 10.1007/s13105-015-0449-1
- Food Standards Australia New Zealand. 2001. Guidelines for the microbiological examination of ready-to-eat foods. Retrieved from https://www.foodauthority.nsw.gov.au/sites/default/files/_Documents/scienceandtechnical/microbiological_quality_guide_for_RTE_food.pdf
- Huang, S., He, Y., Zou, Y. and Liu, Z. 2015. Modification of insoluble dietary fibres in soya bean okara and their physicochemical properties. *International Journal of Food Science and Technology*, 50 (12), 2606-2613, Retrieved from DOI <https://doi.org/10.1111/ijfs.12929>
- Makinde, F.M. and Eytayo, A.O. 2019. The evaluation of nutritional composition and functional and pasting properties of wheat flour-coconut flour blends. *Croatian Journal of Food Science and Technology*, 11 (1), 21-29, Retrieved from DOI <https://doi.org/10.17508/CJFST.2019.11.1.03>
- Nollet, L. and Toldra, F. 2015. *Handbook of food analysis*, Two volume set (3rd ed.). CRC Press, ISBN 9781466556546, Florida, USA.
- Patil, U. and Benjakul, S. 2017. Characteristics of albumin and globulin from coconut meat and their role in emulsion stability without and with proteolysis. *Food Hydrocolloids*, 69, 220-228, Retrieved from DOI <https://doi.org/10.1016/j.foodhyd.2017.02.006>
- Ramaswamy, L. 2014. Coconut flour, A low carbohydrate, gluten free flour, A review article. *International Journal of Ayurvedic and Herbal Medicine*, 4 (1), 1426-1436, Retrieved from <http://interscience.org.uk/v4-i1/1%20ijahm.pdf>
- Ranjan, J. 2017. Coconut fiber for diabetics, A comprehensive guide. Retrieved from <https://www.healthifyme.com/blog/coconut-for-diabetics-a-comprehensive-guide/#:~:text=Coconut%20can%20be%20a%20healthy,25%20grams%20of%20fibre%20daily>
- Richards, L. 2019. The ultimate guide to coconut products. Retrieved from <https://www.thecandidadiet.com/ultimate-guide-to-coconut-products/>
- Sinaga, S.M., Margata, L. and Silalahi, J. 2015. Analysis of total protein and non protein nitrogen in coconut water and meat (*Cocos Nucifera* L.) by using Kjeldahl method. *International Journal of PharmTech Research*, 8 (4), 551-557, Retrieved from [https://sphinxsai.com/2015/ph_vol8_no4/1/\(551-557\)V8N4PT.pdf](https://sphinxsai.com/2015/ph_vol8_no4/1/(551-557)V8N4PT.pdf)
- The Food and Nutrition Research Institute. 2006. *Recommended energy and nutrient intake* (8th ed.). Department of Science and Technology, Philippines.
- Trinidad, T.P., Mallillin, A.C., Valdez, D.H., Loyola, A.S., Askali-Mercado, F.C., Castillo, J.C., Encabo, R.R., Masa, D.B., Maglaya, A.S. and Chua, M.T. 2006. Dietary fiber from coconut flour, A functional food. *Innovative Food Science and Emerging Technologies*, 7 (4), 309-317, Retrieved from <https://doi.org/10.1016/j.ifset.2004.04.003>



An Evaluation of Consumers' Preference for the Organic Rice Commodity in Thailand

NAREERUT SEERASARN*

*School of Agriculture and Cooperatives, Sukhothai Thammathirat Open University,
Noonthauri, Thailand
Email: nareerut.see@stou.ac.th*

SERVEL A. MILLER

*Department of Geography and International Development, University of Chester,
United Kingdom*

Received 31 December 2021 Accepted 11 July 2022 (*Corresponding Author)

Abstract The objective of this study was to towards the growth of the Thai Organic rice industry: An evaluation of consumers' behavior and barriers to organic rice consumption in Thailand. The questionnaire was collected from 223 rice growers using simple random sampling by using the formula of Taro Yamane with 5% variation. The descriptive and inferential statistics were used to answer the research purpose, such as mean percentage, ANOVA statistical analysis. This research found that; confidence in the 'organic-label', cheaper price, quality, nutritional value, range of organic products, accessibility and availability are the key deciding factors to purchase organic rice by consumers. Lack of trust in the authenticity of organic products is a key barrier and farmers needs to understand the certification and quality assurance processes to help them overcome this hurdle. Price is a significant motivator to purchase, as such, initiatives to increase efficiency in production and encourage farmers to plant more pest-resistant/high yielding rice variety is critical. The government certification programme needs to be standardize and utilize innovative technologies including the creation of national 'kite-mark' which provides the ability by the consumers to trace the origin of rice products (e.g. QRcode, augmented reality) to build trust in organic rice products. The research presented underpin the relevance of understanding the extrinsic and intrinsic motivations of consumers' satisfaction to buy organic rice and how this can be used to better inform the development of Government policies.

Keywords organic agriculture, consumer preference, quality rice

INTRODUCTION

The Rice is the staple food for more than half of the world's population and its cultivation, processing, marketing, and its trade influences the livelihoods of billions of peoples around the world (Oyoshi, 2016). For over 700 million Asians who live on less than one (U.S.) dollar a day, rice accounts for nearly 70% of their food intake. In these countries, up to 40% of their income nationally is associated with rice production and trade and up to 80% in rural areas (Sangbuapuan, 2013). In most South-East Asian countries, for example, Thailand, the rice industry (farming, marketing, and trade) is a major employer and contributor to the national economy. As highlighted by the Mekong Common (2016) maximizing the benefits of rice production and trade is of paramount importance for local communities and individuals in Thailand (Mekong Common, 2016). The Thai government through its 20-year strategic plan (2017-2036) has recognized that rice production and trade is not only essential to maintain its economic wealth but is an integral component of ensuring national food security and sustainable rural economic growth (FAO, 2018). As such agriculture growth, especially rice production and trade continue to be one of the government's high priority national agenda according to the Office for Agriculture Economics's report (2017). One strategy to achieve agricultural growth is to increase the production of premium

rice and rice-products that attracts a higher farm-gate price that is of direct benefit local farmers increasing their income. Increasing the productivity of organic rice which is marketed as a premium product and attracts higher price is one the Thai government's strategies (Suwanmaneepong, 2020). As highlighted by the Office of Agriculture Economics (2020), the national agricultural strategy promotes; an increase in production using more sustainable practices, better food safety and enhance national economy through exportation. As a result, many provinces initiated new and large-scale organic food production and processing projects as part of the national agenda and to capitalize on financial incentive being offered by the government (Thanawong et al., 2014). However, understanding the demand for these organic rice products by the Thai public is poorly understood and the Thai government needs to gain a better understanding of consumers' behaviour and barriers to organic rice consumption to drive intervention strategies (Chuasuwana, 2018).

OBJECTIVE

The objective of this study was to towards the growth of the Thai Organic rice industry: An evaluation of consumers' behavior and barriers to organic rice consumption in Thailand.

METHODOLOGY

Data Collection

Data collection was undertaken in Surin province of North-eastern Thailand. The province was chosen as results of it being the leading organic rice-producing area as well as Jasmine rice production.

Data Analysis Descriptive statistics were applied to analyses percentage, arithmetic mean and standard deviation. To test the differences between opinions in organic products purchase and F-test statistics were conducted, after a test of normality was conduct and the conditions satisfied. A significance level of $p < 0.05$ was set for statistical significance. Analysis of variance (ANOVA) was used to determine the differences between annual incomes of focus groups. The goal of the analysis is to test for differences among the means of the levels and to quantify their differences. The dependent-samples t-test was used to determine consumer's difference in attitude, willingness and perception between the different factors. It compares the means of two variables, computes the difference between the two variables for each case, and examines to see if the average difference is significantly different from zero (Mcclave and Benson, 1988). Thematic analysis was done on the data collected using focus groups (Braun and Clarke, 2006).

RESULTS AND DISCUSSION

Table 1 highlights the demographic characteristic of all the respondents surveyed using the questionnaire. Approximately age of the respondents were 23% less than 31 years old, 37% between 31-40 years old, 30% from 41-50 years category and 10% were more than 50 years old. Comparatively, the total sample comprised 66% females and 34% males. The data is naturally skew towards more females, who traditional are the ones who are the main purchase decision-makers in households. Respondent's educational level was categorized into primary school, secondary school, college or university and others. Approximately 6% of respondents attended primary school, 15% secondary school, 73% have attended university/college and 6% fall into the last category of others. The respondents' range of income was categorized into four groups: Less than 15,000 Baht, 15,000-30,000 Baht, 30,001-50,000 Baht, and more than 50,000 Baht. About 26% of the respondents earned less than 15,000 Baht, 31% earned between 15,001-30,000 Baht, 19% 30,001-50,000 Baht and 24% earned over 50,000 Baht. The occupation category was divided into six categories; namely, business, private, housewife, retired, students and others. The results

showed that 33% of the respondents fell into the private job category, and 27% were housewives (Table 1).

Table 1 Demographic characteristics of respondents

1 USD = 30 THB

n =233	
Attribute	Percentage (%)
Age	
Less than 31	23.0
31-40	37.0
41-50	30.0
more than 50	10.0
Mean 41.9, Max 56, Min 22	
Gender	
Female	66.0
Male	34.0
Education level	
Primary	6.0
Secondary	15.0
College/University	73.0
Others	6.0
Annual Income (Thai currency) ¹	
Less than 15,000	26.0
15,000-30,000	31.0
30,001-50,000	19.0
More than 50,000	24.0
Mean 48,465.23, Max 350,000 Min 4,500	
Job or profession	
Business	10.0
Private	33.0
House wife	27.0
Retired	11.0
Student	9.0
Others	10.0

Table 2 The reasons of the respondents for not buying organic products

Statement	Agree (3)	Disagree (2)	Don't know (1)
Unaware of organic food	7.1	28.6	64.3
Nothing beneficial to justify a higher price	10.0	10.7	79.3
Don't trust the label/don't think it is really a certified organic food	8.6	12.9	78.5
Non-organic food is hygienic/safe enough	12.9	11.4	75.7
Too expensive	10.7	7.9	81.4
Too difficult to get	15.0	10.0	75.0

On the other hand, the reasons for not buying organic products (Table 2) are as a result of lack of awareness or insufficient information which is perceived as an important issue. About 7.1% of the respondents agreed, over the lack of awareness of organic rice products while 28.6% disagreed and 64.3% said they don't know. Regarding the trust on certification labels or certified organic food, 8.6% agreed that don't trust the label/don't think it is really a certified organic food while 12.9% disagreed and 78.5% indicated "I don't know". On the respondent's response (either negative or positive) regarding health and environmental issues, approximately 10.7% disagreed with the statement and believed that there is nothing beneficial to justify a higher price against 10.0% who agreed on the same statement. 79.3% do not know. Non-organic food hygiene/safety-

related issues while 12.9% agreed. 11.4% disagreed Of the respondents, 10.7% agreed that it is too expensive to buy, but 7.9% disagreed and 81.4% responded: “don’t know”. About 15% agreed and 10% disagreed gave their reasons as too difficult to get or purchase (Table 2).

Table 3 summarizes consumers’ perceptions and attitudes toward organic rice in our study. The results of analysis of variance (tests) revealed that those unaware of organic food group topped the six-point scale. This implies that the majority of males are comparatively unaware of organic food, nothing beneficial to justify a higher price, don’t trust the label/don’t think it is really certified organic food, non-organic food is hygienic/safe enough, too expensive, too difficult to get organic rice. Based on t-test equal variances not assumed, quasi Sig >.05 was not statistically significant all six point scale.

Table 3 Summary of consumers’ perception and attitude towards organic rice

Statement	Gender				t	p
	Female		Male			
	\bar{x}	S.D.	\bar{x}	S.D.		
Unaware of organic food	2.924	0.965	3.088	0.933	0.814	0.418
Nothing beneficial to justify a higher price	2.287	0.855	2.176	0.833	0.622	0.535
Don’t trust the label/don’t think it is really certified organic food	2.863	1.135	3.205	0.977	0.494	0.138
Non-organic food is hygienic/safe enough	2.197	0.915	2.382	0.921	0.957	0.341
Too expensive	2.848	1.153	3.117	1.174	1.099	0.275
Too difficult to get	2.151	0.915	2.500	1.080	1.695	0.093

Notes: p-values (p) are for the respective tests of standard deviation (S.D.) difference between consumer’s perception and attitude towards organic rice.

Table 4 Compare between income and consumers perception towards organic rice

Items	Income								F
	<15,000		15,000-30,000		30,001-50,000		> 50,000		
	\bar{x}	S.D	\bar{x}	S.D	\bar{x}	S.D	\bar{x}	S.D	
Less expensive	2.846	1.189	3.096	1.193	2.842	1.258	3.041	1.160	0.310
More widely available in the market	2.846	1.155	2.935	1.123	3.000	1.154	3.000	1.103	0.267
More assortment availability	2.923	1.092	3.032	1.139	3.052	1.129	2.875	1.191	0.192
Better appearance and taste	2.384	0.941	2.354	0.950	2.315	0.820	2.291	0.858	0.154
More trust to origin/ production	2.538	1.139	2.709	1.101	2.210	1.031	2.416	1.059	0.958
Good for health	3.000	1.095	3.032	1.196	2.894	1.328	2.750	1.293	0.668
Others	2.461	1.139	2.387	1.308	2.421	1.216	2.333	1.203	0.104

Table 4 The data in Table 4 indicates that consumers tend to purchase more organic food if it is less expensive, for the income group earning < 15,000 baht, between 15,000 and 30,000 baht; between 30,001 and 50,000 baht, and those earning > 50,000 baht, However, respondents with income are more the satisfaction to buy if the prices are less expensive which means higher price elasticity and between income and consumers perception towards organic rice. Based on F-test Equal Variances not assumed, quasi Sig >.05 was not statistically significant all items.

The data showed that private-sector employees constitute 33% of the respondents and housewives 27%. Most of the respondents (73%) have a college or university education. It should be noted that Surin town though a small rural provincial capital, is home to three universities. Similarly, a previously published study (Sangkumchaliang and Huang, 2012) showed that in the rural provinces of northern Thailand, most of the organic purchasers have college degrees or higher. This high-level awareness could be due to the fact that Surin province is one of the top organic farming areas in Thailand but also has quite well developed and organized organic marketing system. Hence, people support the organic farmers as much as they could afford as organic food is much more expensive than non-organic food. From the survey, their main motivating reasons for buying organic food are food safety, healthy, good taste and good nutrition. Consumer preference for organic food is based on the general perception that organic products have more desirable characteristics than conventionally grown alternatives (Tsakiridou et al., 2008; Magistris and Gracia, 2008). Numerous research (e.g. Bonti-Ankomah and Yiridoemm, 2006; Roitner-Schobesberger, 2006; Sangkumchaliang and Huang, 2012) highlighted that the main reason for buying organic foods is the perception that they are generally safer, healthier and environmentally friendly than conventionally produced food. Providing training to farmers on safe practices, certification, how to maintain organic status and marketing of the nutritional value of their rice will help keeping their business profitable. Extension officers helping farmers to better understand consumer preferences and attitude is key to help them market their product more effectively.

From this research the main grouses are that organic food is too expensive, and consumers are doubt full about the certifications and labelling. Bonti-Ankomah and Yiridoe (2006) suggested that the relatively high “price- elasticity” of organic products is because of consumers’ high sensitivity to price changes, which predominantly contributes for them rejecting organic products. Government policies therefore needs to be developed to encourage more funding of the organic rice sector. In the short-term subsidizing the cost, equipment, strengthening local cooperatives and provide farmers with mechanism (for example setting-up of online market place/portals, warehousing facilities) to sell their product directed to market (reducing the number of intermediary channels) may be viable solution. In the long-term research in for example more “pest-resistance” strain of rice, “organic- friendly” weed control, smart-technologies to monitor and optimize production, improvement in harvesting technologies are essentials. Developing an extension strategy to address the use of technologies and more effective pest/week control are integral in reducing price of organic rice and increasing production (Nareerut et al., 2020; Nuttavuthisit and Thøgersen, 2017; Weisberg et al., 1996).

This research found that the four principal factors that boost the popularity of organic food are: (1) cheaper price, (2) sustaining the quality of the produce in accordance to good health and nutrition requirements, (3) production of a variety of organic products, and (4) increasing its accessibility and availability to be more competitive against conventional food products as similarly suggested by Bonti-Ankomah and Yiridoe (2006). By increasing the organic market share and hence stimulating bigger production volumes, the economy of scale kicks in to reduce the unit production cost and retail price even lower. This will create a multiplier effect to produce even higher quantities and greater varieties of organic food. There will be more wholesalers and retailers in the supply chain to make it cheaper and more widely available. This cannot happen without significant investment in the development of better pest resistant and high yielding variety. The failure of Thailand rice to win top awards for the development of more high yielding organic variety in recent years, is an indication of the research and development work require by the Thai agriculture ministry (Ploenpotea, 2019). Farmers, needs to be trained and make aware of the best way to use these varieties and utilise more innovative methods for example smart farming technology to increase efficiency and farms. The role of extension officers is key in providing this education and training, but these need increase in investment by government to facilitate this. As such, we recommend that government continues to invest and subside farms that wishes to switch to organic farming and put in place more research and development initiative to develop better rice variety to improve productivity and efficiencies that will encourage more farmers to take up organic farming, which some currently view as not being financially viable.

CONCLUSION

The consumption of organic food is steadily increasing because of concerns over environmental and health issues associated with food production. The higher consumer interest in organic food products is attributed to the growing demand for food free from pesticides and chemical residues. It is evident that organic food is popular and has excellent potential in Surin province. Most consumers agree that organic food has many advantages over conventionally grown food for reasons of food safety, chemical-free and better taste and nutrition. Many consumers in Surin province are aware of organic rice, and approximately 66% have purchased organic food before and still purchase it.

This research found that the principal factors that boost the popularity of organic food are; confidence in the 'organic-label', cheaper price, sustaining the quality of the produce in accordance to good health and nutrition requirements, production of a variety of organic products, and increasing its accessibility and availability to be more competitive against conventional food products. Government policies need to be better geared towards raising the awareness of the benefit of organic food products to a more diverse group beyond the typical consumers (female, with university education and high-income earners). Price is a significant constraint to consumer switching to organic rice purchase. Government policy (including availability of funding/loans, ability for farmers to purchase land, subsidies and education programme for farmers development better farm management practices) needs to be strengthened and continued in order to encourage more farms to switch to organic rice production. Extension programme will play a key role in educating farmers and help them to better produce and market products suitable for the consumers. By stimulating bigger production volumes, the economy of scale kicks in to reduce the unit production cost and the retail price even lower. This will create a multiplier effect to produce even higher quantities and greater varieties of organic food. There will be more wholesalers and retailers in the supply chain to make it cheaper and more widely available. This research also highlights that trust in the 'organic rice' label is also a major barrier to purchase. Organic Rice is not only recognized and popular in the urban cities but also in the rural provinces with higher exposure to higher education, information and involved in organic production. More considerable attention, effort, resources and better policies from all stakeholders can popularize organic products to be more affordable, widely available and trusted to consumers.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the School of Agriculture and Cooperatives, Sukhothai Thammathirat Open University. The authors would also like to thank the Rice Research Centre, Ms. Nirada Paennangrong, and Mrs. Chananath Chana-akson for their invaluable field support and access to reports and documents, and for facilitating access to the farming community and stakeholders. The views and opinions expressed in this study are those of the authors; the Asian Journal of Agriculture and Rural Development shall not be responsible or answerable for any loss, damage, or liability, etc. caused in relation to/arising out of the use of the content.

REFERENCES

- Aryal, K.P., Chaudhary, P., Pandit, S. and Sharma, G. 2009. Consumers' willingness to pay for organic products, A case from Kathmandu Valley. *Journal of Agriculture and Environment*, 10, 12-22, Retrieved from DOI: <https://doi.org/10.3126/aej.v10i0.2126>
- Bangkok Post. 2019. Make thai rice great again. Bangkok Post Editorial Column, Retrieved from <https://www.bangkokpost.com/opinion/opinion/1801339/make-thai-rice-great-again>
- Basha, M.B., Mason, C., Shamsudin, M.F., Hussain, H.I. and Salem, M.A. 2015. Consumers attitude towards organic food. *Procedia Economics and Finance*, 31, 444-452, Retrieved from DOI [https://doi.org/10.1016/S2212-5671\(15\)01219-8](https://doi.org/10.1016/S2212-5671(15)01219-8)
- Bonti-Ankomah, S. and Yiridoe, E.K. 2006. Organic and conventional food, A literature review of the economics of consumer perceptions and preferences. Final Report, Organic Agriculture Centre of

- Canada. Retrieved from https://www.researchgate.net/publication/229051543_Organic_and_conventional_food_A_literature_review_of_the_economics_of_consumer_perceptions_and_preferences
- Bourn, D. and Prescott, J. 2002. A comparison of the nutritional value, sensory qualities and food safety of organically and conventionally produced foods. *Critical Reviews in Food Science and Nutrition*, 42 (1), 1-34, Retrieved from DOI <https://doi.org/10.1080/10408690290825439>
- Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77-101, Retrieved from DOI [10.1191/1478088706qp063oa](https://doi.org/10.1191/1478088706qp063oa)
- Briz, T. and Ward, R.W. 2009. Consumer awareness of organic products in Spain, An application of multinomial logit models. *Food Policy*, 34 (3), 295-304, Retrieved from DOI <https://doi.org/10.1016/j.foodpol.2008.11.004>
- Chetchuda, C. 2018. Thailand industry outlook 2018-2020 rice industry. Retrieved from <https://www.krungsri.com/bank/getmedia>
- De Magistris, T. and Gracia, A. 2008. The decision to buy organic food products in Southern Italy. *British Food Journal* 110 (9), 929-947, Retrieved from DOI <https://doi.org/10.1108/00070700810900620>
- Food and Agriculture Organization (FAO). 2018. Thailand country fact sheet on food and agriculture policy trends socio-economic context and role of agriculture. Retrieved from www.fao.org/3/I8683EN/i8683en.pdf
- Kongsom, W. and Kongsom, C. 2016. Consumer behavior and knowledge on organic products in Thailand. *International Journal of Economic and Management Engineering*, 10 (8), 2524-2528, Retrieved from <https://zenodo.org/record/1125639/files/10004971.pdf>
- Krystallis, A. and Chrysohoidis, G. 2005. Consumers' willingness to pay for organic food, Factors that affect it and variation per organic product type. *British Food Journal*, 107, 320-343, Retrieved from DOI <https://doi.org/10.1108/00070700510596901>
- Kuchler, F. and Golan, E. 1999. Assigning values to life, Comparing methods for valuing health risks. Food and Rural Economics Division, Economic Research Service, Department of Agriculture, Washington DC, Retrieved from https://www.ers.usda.gov/webdocs/publications/41093/52100_aer784.pdf?v=0
- Mekong, C. 2016. Organic rice in Northeastern Thailand: improving farmers' livelihoods and the environment. Retrieved from <http://www.mekongcommons.org/organic-rice-northeast-thailand-improving-farmers-livelihoods-environment/>
- Nuttavuthisit, K. and Thøgersen, J. 2017. The importance of consumer trust for the emergence of a market for green products, The case of organic food. *Journal of Business Ethics*, 140, 323-337, Retrieved from DOI <https://doi.org/10.1007/s10551-015-2690-5>
- Office of Agriculture Economics. 2017. Weekly production and marketing situation. Retrieved from [http://www.oae.go.th/view/1/Weekly production and marketing situation /TH-TH](http://www.oae.go.th/view/1/Weekly%20production%20and%20marketing%20situation/TH-TH)
- Office of Agricultural Economics. 2020. Weekly production and marketing situation. Retrieved from [http://www.oae.go.th/view/1/Weekly production and marketing situation /TH-TH](http://www.oae.go.th/view/1/Weekly%20production%20and%20marketing%20situation/TH-TH)
- Oyoshi, K., Tomiyama, N., Okumura, T., Sobue, S. and Sato, J. 2016. Mapping rice-planted areas using time-series synthetic aperture radar data for the Asia-RiCE activity. *Paddy and Water Environment*, 14 (4), 463-472, Retrieved from DOI <https://doi.org/10.1007/s10333-015-0515-x>
- Roitner-Schobesberger, B., Darnhofer, I., Somsook, S and Vog, C.R. 2006. Consumer perception of organic foods in Bangkok, Thailand. *Food Policy*, 33 (2), 112-121, Retrieved from DOI <https://doi.org/10.1016/j.foodpol.2007.09.004>
- Ruekkasaem, R. and Sasananan, M. 2017. The factors affecting decisions to purchase rice and consumer perception of organic rice in Bangkok, Thailand. *Journal of Advances in Agricultural and Environmental Engg.*, 4 (1), 6-11, Retrieved from <https://iicbe.org/upload/5635C0117028.pdf>
- Sangbuapuan, N. 2013. Strengthening the rice production in thailand through community rice centers (CRCs) using ICT policies. 2013 IEEE/ACIS 12th International Conference on Computer and Information Science (ICIS), Retrieved from <https://ieeexplore.ieee.org/document/6607899>
- Sangkumchaliang, P. and Huang, W.C. 2012. Consumer's perceptions and attitudes of organic food products in Northern Thailand. *International Food and Agribusiness Management Review*. 15 (1), 87-102, Retrieved from https://ageconsearch.umn.edu/record/120860/files/20110057_Formatted.pdf
- Seerasarn, N., Miller, S.A. and Wanaset, A. 2020. Transitioning to organic rice farming in thailand, Drivers and factors. *Asian Journal of Agriculture and Rural Development*, 10 (3), 740-748, Retrieved from DOI <https://doi.org/10.18488/journal.ajard.2020.103.740.748>
- Strzok, J.L. and Huffman, W.E. 2012. Willingness-to-pay for organic food products and organic purity, Experimental evidence. Working Paper No. 12017, Department of Economics, Iowa State University, Retrieved from <http://www2.econ.iastate.edu/papers/p15502-2012-09-24.pdf>

- Suwanmaneepong, S., Kerdsriserm, C., Lepcha, N., Cavite, H.J. and Llonas. 2020. Cost and return analysis of organic and conventional rice production in Chachoengsao province, Thailand. *Organic Agriculture*, 10 (3), 369-378, Retrieved from DOI <https://doi.org/10.1007/s13165-020-00280-9>
- Thanawong, K., Perret, S.R. and Basset-Mens, C. 2014. Eco-efficiency of paddy rice production in Northeastern Thailand, A comparison of rain-fed and irrigated cropping systems. *Journal of Cleaner Production*, 73 (15), 204-217, Retrieved from DOI <https://doi.org/10.1016/j.jclepro.2013.12.067>
- Tsakiridou, E., Boutsouki, C., Zotos, Y. and Mattas, K. 2008. Attitudes and behavior towards organic products, An exploratory study. *International Journal of Retail and Distribution Management*, 36 (2), 158-175, Retrieved from DOI <https://doi.org/10.1108/09590550810853093>
- Weisberg, H.F., Krosnick, J.A. and Bowen. B.D. 1996. *An introduction to survey research, polling, and data analysis* (3rd ed.). Sage Publications, London, UK.
- Wijesinghe, A.G.K and Nazreen, A.H.P. 2020. Consumer willingness to pay for organic rice, With reference to Kurunegala district in Sri Lanka. *Kelaniya Journal of Management*, 9 (1), 35-46, Retrieved from DOI <http://doi.org/10.4038/kjm.v9i1.7621>
- Williams, K.C. and Page, R.A. 2011. Marketing to the generations. *Journal of Behavioral. Studies in Business*, 3 (1), 37-53, Retrieved from <https://citeseerx.ist.psu.edu/document?Repid=rep1&type=pdf&doi=4cc13ef8b6e1e4b1ab8c1dd54290ad0d31d5dad>
- Yamane, T. 1973. *Statistics, An introductory analysis* (3rd ed.). Harper and Row, New York, USA.



The Legacy of the Waternetwork from the Past: Characteristics and Types of the Covered Waterways in Tokyo

IVANA ANGELOVA*

*Meiji University, Tokyo, Japan
Email: ivanaangelova@meiji.ac.jp*

DAVISI BOONTHARM

Chulalongkorn University, Bangkok, Thailand

MASAMI KOBAYASHI

*Meiji University, Tokyo, Japan
Email: mkob@gol.com*

Received 31 January 2022 Accepted 18 July 2022 (*Corresponding Author)

Abstract Edo was once a city of water and everyday life was intertwined with its rich water network. Unfortunately, the connection with water was lost due to the rapid urban growth of the city and now most of the local scale water streams in Tokyo are culverted. They have turned into green streets and their tributaries into narrow pathways. The objective of this study is to trace the covered waterways in the broader network of the blue and green infrastructure of the city and to catalogue them in accordance with their different features like design and usage. In the first part, analysis is done on the legacy of the urban streams from Edo to Tokyo. Furthermore, the methodology and the results of the research are presented, showing a map of the covered waterways and their classification. For this reason, two different scales of the linear elements are assessed. The findings show that, based on a short section, considering the width and landscape design, there are four groups of types of which three are covered kind of types. Based on assessing a few hundred meters long segment, there are five groups of types based on their primary usage each having two sub-types except for the last that has only one. According to the results a conclusion is drawn that today most of the covered streams in the city have some commonalities in their design and how people use the space. Typically, the route of most of those ancient streams is accompanied by endless kilometers of pedestrian and cycling paths regarded as "green ways". Together they form a rich network spreading throughout the city. They represent inclusive public spaces that plays a vital part in strengthening communities and need further research.

Keywords Tokyo, covered waterways, legacy, scales, typology

INTRODUCTION

Since its formation up until the end of Edo (old name of Tokyo) the city has been compared to Venice and Amsterdam in Europe. Unfortunately, the connection with water was lost due to the rapid urban growth of the city, especially after the Olympics in 1964 when many of the rivers and streams were covered by roads and now remain as hidden waterways. In his book *Tokyo: A Spatial Anthropology*, the renowned architectural historian Hidenobu Jinnai, 1995 states that water was the element that brought people together and the first public spaces in the city of Tokyo emerged on the riverbanks and around bridges. He argues that the waterways today, even though overlooked in the planning practices, are an asset so valuable as to make Tokyo stand up as a unique nature-based metropolis of the future. But even though "Edo- a beautiful city integrated into the great natural

world” today “the city itself faces a crisis because we, the citizens of present-day Tokyo are discarding this legacy in the name of functionality and efficiency (Jinnai, 1995)”.

In the past decade a growing number of literatures appeared with the aims to evoke the water network of Tokyo. Moreover, in the midst of scrap and build culture, the attention is growing stronger for permanent elements in the city such as topography and terrain (Jinnai, 2017). While the existing works are focused in exploring the appearance and geographical features of the open and hidden waterways, a more comprehensive study is lacking in the field of their identification and cataloguing based on different features.

Therefore, this study is trying to fill the knowledge gap by adding more valuable information for studying the urban open and covered water network. Emphasis is given in exploring the smaller scale streams which have a local character and are mostly culverted and transformed into greenways. Both primary and secondary data are used to meet the objective of this study. Quantitative data comes in form of a map showing the covered streams and empirical data is presented by their classification by two different factors.

URBAN WATERWAYS TROUGH HISTORY

The city’s connection to water through history is giving a background to the phenomena of the hidden waterways today. Using literature review and historical maps, three points in history are recognized as major water related transformations. Fig. 1 shows the timeline and the consequences of urban transformation to water in each period.

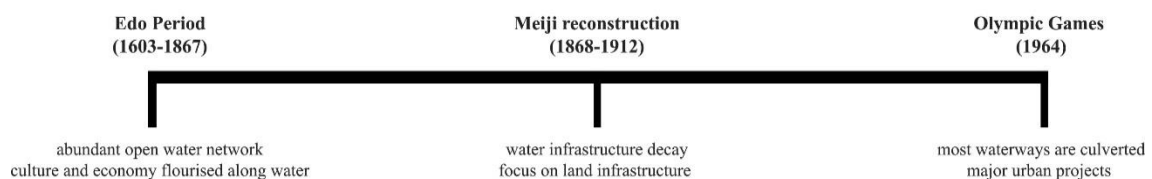


Fig. 1 Waterway transformation timeline for Tokyo

Edo Period (1603-1867): *Tokyo Aquatic*

Tokyo is a legacy of the original urban planning of Edo, the old name of the city. By definition the word ‘Edo’ equals an ‘estuary’. This period was the most fruitful for the city expansion and the establishment of its wider structure that grew along with the spiraling moat system. The rich water network enabled a close connection to water for the people in the marsh lands. All sorts of commercial, cultural and even spiritual activities happened along the riverbanks in the low land Edo. Water is depicted in more than 80% of the paintings in “One Hundred Famous View of Edo”, showing how entrenched it was in the livelihood of the people. Many of the shrines and temples were faced towards the water edge. In the peripheral areas of the city, numerous townships produced food and transported it by boats to central Edo making use of the rivers and aqueducts. According to the land use of Edo, over 40% of the land was used for farming (Fujii et al., 2002), Edo was a garden city making use of the abundance of water. As the city was growing over time, it took an organic shape respectful of the natural topography and conditions. “The city has been built with knowledge of its vulnerability to natural forces (Shelton, 2012) “. In this period not only did the city blueprint was established but also the cultural and social life reached its peak. Water brought value to people’s life and there was a very sophisticated and sustainable water treatment unbeknownst to any western civilization at the time.

Meiji Restoration (1868-1912) and Taisho Period (1912-1926): *Channelizing Urban Waterways*

Meiji Era came as the time of industrialization and implementation of Western ideologies. To keep up with the trend of technological advancements, the process of industrialization took on a high

speed in Japan. Neoclassical approach in the urban planning and architecture practices of the time was applied on top of the old layers of the city (Hein, 2008). Major transportation networks for cars and trains were planned but were not fully constructed due to the scarcity in resources after World War I. As land transportation took over, local streams were left neglected, and the lively riverbanks slowly lost their cultural value and were left to serve as mere industrial complexes. Moreover, the city's water-based structure experienced a second huge disruption when the devastating Great Kanto earthquake of 1923 caused a myriad of uncontrolled fires that left devastating consequences on people's lives and their environments. This natural disaster has led to reevaluation of the waterside spaces and their safety. The event marked the beginning of channelizing the city's waterways. The disaster response was a clear sense that "Japan had been granted an unprecedented chance to upgrade the city. (Charles, 2008) ".

Showa Era (1926-1989) to Modern Tokyo: Local Culverts

Showa period is represented by two contrasting periods, before and after World War 2. After the devastating raid that took over the city during the war, it took 6 years to completely recover. This period is when most of the waterways were covered due to safety, aesthetic and land reclamation reasons. In the upheaval period after the 50s big urban plans for the city were executed and local urban planners adopted the ideas that could easily implement the concept of *machi*-small town "comprised of many small towns with different purposes (Hein, 2008)". In line with those ideologies, planning principles from the 20s and 30s were adopted that emphasized polycentricity and green areas in between neighborhoods. In Tokyo Olympic Games land-based infrastructure grew immensely in order to give the city a new international look. There was a boom in the construction of expressways and many of the rivers and canals were left covered by the elevated road structures. This period of intense construction led to huge environmental crisis. The smaller scale waterways were contaminated, and people complained from the bad smell. Taking in consideration the natural disaster prevention management and the decay of the local streams, decisions were made to culvert most of them. In the 80s Tokyo was re-discovered as a city on water. Old societal ideologies that celebrated the connection to the natural environment and culture were reconsidered and gained popularity. Appreciation for the local qualities emerged again. Urban policies for the protection of water and greenery, and conservation of historical sites were established. Many waterside regeneration projects took part like converting the river coast into public leisure areas (Jinnai, 2017). Smaller and more local initiatives took interest in revival of the covered waterways that continued through the 90s.

Present Day Tokyo: Reconsidering the Role of the Local Culverts

Today Tokyo represents the largest city in the world, an agglomeration of many *machi*, a polycentric city (Shelton, 2012). The township culture is still kept until the present day, providing a sense of authenticity and belonging, a vital factor for strengthening communities (Kuma et al., 2021). Even though due to strong globalization forces the city has drastically lost its rural landscape and connection to water, the legacy of the abundant water network is kept in the form of myriad of greenways curving their way in the city landscape. They are very much used and treasured by the citizens.

Future brings challenges, and for Japan the main one is the demographic change, natural disasters and public debt (Ohno, 2018). When the challenges mentioned above translates onto the city landscape, it is expectable to see some urban patterns completely change. One of the repercussions will be the decaying infrastructure in suburban areas caused by the drop in residential density. According to Hidetoshi Ohno, in this scenario the city will be reduced to smaller centers with inclination towards urban greenery, supported with the creation of new open spaces. Reconsidering the role of the linear public spaces created on top of the culverted waterways is crucial for addressing the forthcoming challenges. It is important to examine what kind of asset those elements represent for the quality of life of the city dwellers.

OBJECTIVE

Public spaces can solve a number of the above-mentioned challenges at once. They contribute for the increase of biodiversity, humans' health and pollution. In the Japanese setting public spaces such as plazas do not exist but instead, multiple sites for social interchanges have been constructed to the scale and form that are appropriate to the Japanese physical and cultural context. Many of the small-scale common spaces are overlooked in the urban research practices but are frequently used and often exclusively known by locals. The linear public space, the path on top of the culverted rivers is such a place. Thus, this research is trying to address the importance of this urban phenomena in the context of Tokyo.

The objective of this study is to, initially, identify the location of the covered waterways in the broader network of the blue and green infrastructure in the city and, subsequently, to identify and group them in accordance with their design features and the way people use them. The study location is within Tokyo 23 Special wards. According to the classification given by Bureau of Construction (2015) there are Class A, Class B and Secondary rivers or streams. This research is focusing on the secondary rivers that can be either covered or open and are administrated by the wards.

METHODOLOGY

A research design was developed in an integrated manner to guide each phase of the research. Table 1 (Yin, 2014) defines a research design as a coherent and logical plan to collect data, measure and analyze the data collected, connecting empirical information to the research question and its conclusion. The research design created for this study is comprised of five consecutive parts: *Research question; Source of data; Methods of data analysis; Data processing & tools and Result*. In the first phase of the research, three questions were modelled in relation to the objective of the study. Secondary, the source of data needed to answer each of the question is identified. Primary data is being collected through extended systemized fieldwork of one year, from April 2020 to April 2021, using the map of covered waterways developed in the first phase of the study. Secondary data is collected from official digital maps, namely the online database from National Land Numerical Information in conjunction with Google Satellite View and the authors own fieldwork mapping based on observation. Methods of data analysis show how the data was studied. 20 samples were used to classify the waterways in question 2 and 3. To process the data, tools such as QGIS software, LiDAR 3D camera and Google Street View were used to process the data. The expected results from each research question are presented at the end of the research design.

Table 1 Research design

Research question	Source of data	Methods of data analysis	Data processing & tools	Result
1. What part of Tokyo's waterway network is covered?	Secondary data (National Land Numerical Information & Google Satellite View) + Primary data (field research)	Spatial distribution analysis	Overlaying both sources of data in GIS (Geographic Information System) software	Map of Tokyo metropolitan area showing open and covered waterways
2. What kind of waterways are there according to design?	Primary data (field research) + Secondary data (Open street Map)	Comparative analysis of 20 samples of waterways short sections.	LiDAR camera and Open Street Map measurement tool to measure the width of short sections	Classification based on types of design
3. What kind of waterways are there according to primary usage?	Primary data (field observation) + Secondary data (Google Street View)	Comparative analysis of 20 samples of waterways line segments.	Field observed data and Google Street View recordings of line- segments	Classification based on types of use (including design)

RESULTS AND DISCUSSION

A digital map of Tokyo metropolitan area is showing what part of the water network of the city is covered and is serving as green corridor and what part of it are open rivers and streams is shown in Fig. 2. For data on the overall water network in the city the GIS Data on waterways from National Land Numerical Information (in blue) is used. To make a clear distinction between covered and open streams, data from Google Satellite view, municipality maps of greenways and field observation maps were combined to trace the covered streams (in red). Findings show that while there are a total of 712 kilometers of urban waterways, 490 kilometers or 68% are covered. In terms of distribution by districts, Edogawa ward has the largest number of waterways in total while Setagaya ward has the largest number of covered waterways landscaped like greenways.

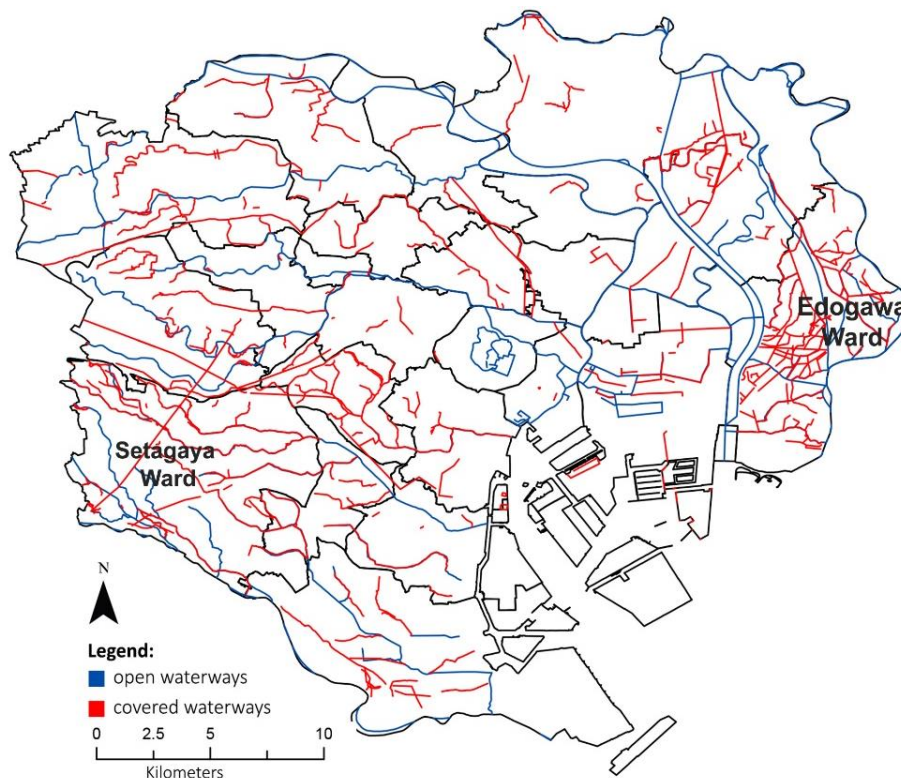


Fig. 2 Map of open and covered waterways in Tokyo

Given the linear shape of the waterway, varieties in use and design can be different in different segments. The same waterway can have a portion with an open stream and a portion of it that is culverted. However, in most cases the treatment is the same for the whole waterway. It is either open or covered. To respond to the second research question, a method was established that focused on the design on a waterway in a micro scale of a few meters long. The width of the waterway and its landscape design, the use of the adjacent streets like vehicle or pedestrian and the land use of adjacent plots were taken in consideration. After an extensive field observation, 20 samples of short sections of different waterways around the city were chosen to test the method. The types and their categorization into groups are presented in Fig. 3. According to the overall design there are four sub-typologies in the *large size group*, 5-12 meters wide. All of them are open. The other three groups represent the covered streams: *medium size*, 3-6 meters wide, typically landscaped like a greenway that can have surface water; *small size*, 2-4 meters wide, narrower greenways; *extra small size*, 1-3 meters wide, narrow pathways. The medium and the small size have four sub- types of covered streams while the extra small size only two.

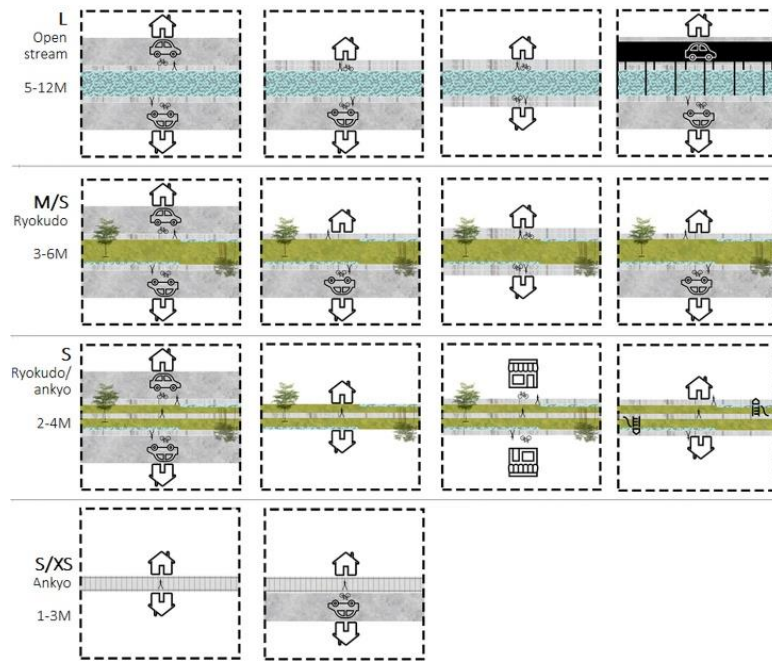


Fig. 3 Types of waterway segments based on landscaping

In terms of the primary usage of the waterway, it depends on the context of where they are located. For example, a stream can run through a commercial area or a residential area which in terms results in different characteristics of use. To respond to the third research question, a method was established that focused on usage of a waterway in a meso scale, of a few hundred meters long. This method tested 20 samples of line segments based on the frequency of users and type of activities they were doing there.

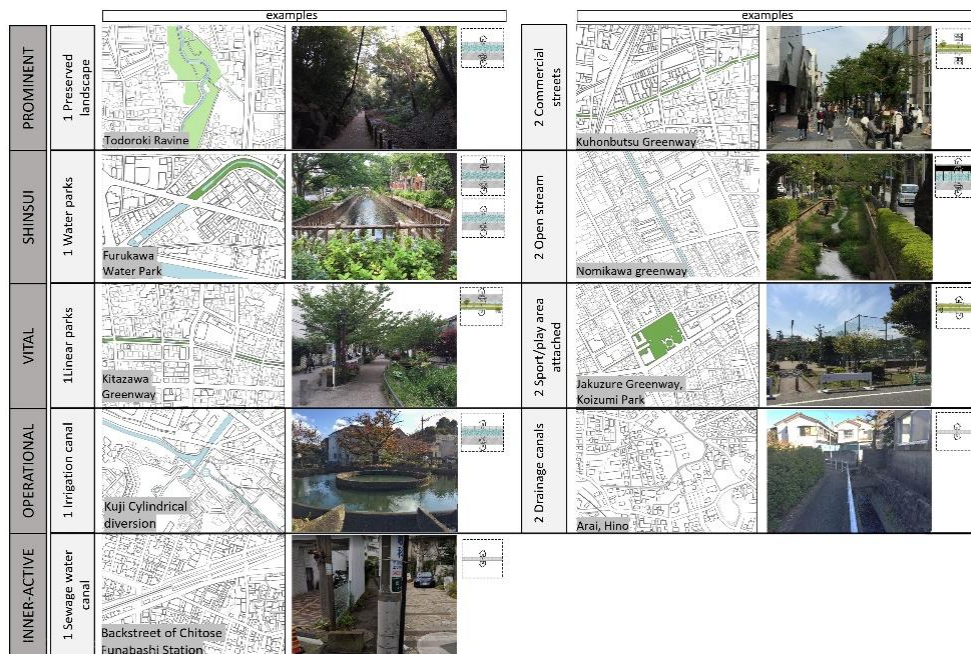


Fig. 4 Types of waterways in line-segments based on their usage

Fig. 4 shows the classification according to the types of use. They are categorized into five main groups: *prominent*-high intensity in use and popularity; *shinsui*-landscaped for water play and

enjoyment; *vital*-long greenways that connect neighborhoods; *operational*-used for irrigation and drainage on the outskirts of the city; *inner-active*-narrow lanes. Each main type has several sub-types. The Prominent type: *preserved landscape*-protected nature with an open stream and *commercial street*-culverted stream in the middle of a commercial zone. The Shinsui type: *water parks*-landscaped as a water park playground and *open stream*-not landscaped as a water park but used as such. The Vital type: *linear park*-landscaped as a greenway and *sport/play area attached*-playground or a sport field is attached on the greenway. The operational: *irrigation canal*-supplying water for urban farming and drainage canals-small scale open type runoff water. The inner-active: *sewage water canal*- small scale pedestrian street.

CONCLUSION

The study examined two different scales of the urban waterways. Looking in the micro scale, it can be observed that different design principles were used to landscape the covered streams. Most of them are landscaped like linear parks with greenery and some have surface water or even water parks for play. In general, they are inclusively designed for pedestrian activity while most often than not, cycling is prohibited. The adjacent streets mainly have a controlled vehicle activity with speed and use limits. The land use of the area where the covered waterways flow is primarily residential and often times there are schools or sport fields attached to the waterway. In the meso scale different types of activities were observed. People used the space in accordance with its landscaping and the location of the waterway. For example, in the commercial zone people used those elements as pedestrian streets and rarely for recreational activities, while the water park and the greenway type saw a huge amount of people doing leisure activities. In conclusion the covered streams have a specific social, spiritual and environmental dimension. Today a new culture of life related to water, different from that of the past emerged after culverting the streams. A culture specific to the Japanese context of public space use and the challenges of the contemporary way of life. A further exploration of their quality as single linear entities and that of the network quality should be done to understand the broader implications of this urban phenomena in the whole city of Tokyo. For this matter the proposed methodology should be broadened to include an inductive approach for analyzing qualitative data.

REFERENCES

- Bureau of Construction. 2015. Tokyo Metropolitan Government, Retrieved from <https://www.kensetsu.metro.tokyo.lg.jp/english/jigyoku/river/02.html>
- Fujii, M., Yokohari, M. and Watanabe, T. 2002. Identification of the distribution pattern of farmlands in Edo. City Planning Review Special Issue, 37, 931-936, Retrieved from DOI <https://doi.org/10.11361/cpij1.37.0.931.0>
- Hein, C. 2008. Machi, neighborhood and small town, The foundation for urban transformation in Japan. Journal of Urban History, 35 (1), 75-107, Retrieved from DOI <https://journals.sagepub.com/doi/10.1177/0096144208322463>
- Jinnai, H. 1995. Tokyo, A spatial anthropology. University of California Press, ISBN-13 978-0520071353, USA.
- Jinnai, H. 2017. Evolutional steps toward the post-western / non-western movement in Japan. Built Heritage, 1, 44-53, Retrieved from DOI <https://doi.org/10.1186/BF03545674>
- Kuma, K., Jinnai, H. and Radovich, D. 2021. Discussion, Tokyo, The right to the city? Infraordinary Tokyo, The right to the city. a+u Architecture and Urbanism, November 2021 Special Issue, 176, Japan.
- Kuma, K., Jinnai, H. and Radovich, D. 2021. Discussion, Tokyo, The right to the city. Architecture and Urbanism Magazine, Special Issue, 176, 6-9.
- Ohno, H. 2016. Fiber city, A vision for the shrinking megacity, Tokyo 2050. University of Tokyo Press, ISBN-13:978-4130668552, Japan
- Schencking, J.C. 2008. The great Kanto earthquake and the culture of catastrophe and reconstruction in 1920s Japan. Journal of Japanese Studies, 34 (2), 295-331, Retrieved from DOI <http://dx.doi.org/10.1353/jjs.0.0021>

- Shelton, B. 2012. *Learning from the Japanese city, West meets east in urban design*. Taylor and Francis, ISBN-13:978-0419223504, UK.
- Yin, K.R. 2014. *Case study research design and methods (5th ed.)*. Sage Publication, ISBN-13 978-1452242569, USA.



Awareness and Compliance of Corn Farmers to Good Agricultural Practices (GAPs) in Nueva Vizcaya, Philippines

JANE B. BACANI*

Nueva Vizcaya State University, Bayombong, Nueva Vizcaya, Philippines

Email: janebbacani@gmail.com

Received 30 December 2021 Accepted 18 July 2022 (*Corresponding Author)

Abstract This study investigated the level of awareness and extent of compliance to certification of corn farmers with Good Agricultural Practices (GAPs) in corn development projects in the cluster municipalities of Nueva Vizcaya. The study sought to determine the demographic characteristics of the respondents, their level of awareness in GAP corn certification requirements, and extent of compliance in GAP corn certification. One hundred sixty (160) corn farmers who are active participant in GAP corn project were randomly selected. Descriptive statistics such as frequency counts, percentages, and mean were used in describing the demographic characteristics of the respondents. A four-point Likert-type scale was used to analyze the level of awareness and extent of compliance. The result revealed that both men and women are active corn farmers, older farmers, most have formal education, smallholder farms, more experience in farming and members in farmers' organization and cooperatives. Likewise, the study indicated a high awareness of the respondents in GAP corn certification requirements gained through their participation to various GAP and GAP-related trainings and activities while compliance to GAP certification is moderate which resulted to low certified corn farms in Nueva Vizcaya. Demographic profile such as sex, education and trainings have positive correlation to the respondents' awareness, however, there is no significant correlation to their compliance.

Keywords GAP, awareness, compliance, certification requirements

INTRODUCTION

Good Agricultural Practices (GAP) certification is a stamp of safety and genuine freshness (ATI, 2013). The Philippine GAP program is a government certification program with the Department of Agriculture as the certifying body. The enactment of Republic Act No. 10611 otherwise known as "Food Safety Act of 2013" strengthens the food safety regulatory system in the country (Official Gazette of the Philippines, 2013). The GAP standard requires a scrutiny of the history of the farm site and its prior; the type of soil, and its compatibility with crops and seed sources; the judicious use of agrichemicals; the sources of potable water for irrigation and washing of crops; the harvest and post-handling procedures; the health and hygiene of the farmer and handlers, and other factors. Aside from scrutiny, the GAP standard also requires systems to be set in place such as sanitary facilities, safe storage areas, post-harvest infrastructure, a paper trail for traceability, among others (PNS, 2017). The Code of GAP for corn is a set of consolidated safety and quality standards prepared by the Department of Agriculture for the production, harvesting and on-farm postharvest handling and storage of corn. The emphasis is to decrease the hazard of pesticide use and aflatoxin contamination. GAP corn was officially launched in 2014, and it became more intensive since the passing of RA 10611 due to inappropriate use of pesticides and other chemicals in farming that pose a hazard to both human and animal health.

The national trend of low GAP adoption is reflected in the Province of Nueva Vizcaya in the Northern part of the Philippines. That despite its intensive implementation and government support, the adoption and certification for GAP corn is still very low, a measly 1.78% in the corn cluster areas, hence, this study investigated the awareness and extent of compliance of corn farmers to

Good Agricultural Practices (GAP) which is a prerequisite to adoption and certification. The purpose is to identify the requirements with low compliance as basis of the implementers for planning. Likewise, it will be relevant to the corn farmers to appreciate good agricultural practices in general and the GAP corn in particular and for them to realize the requirements they have complied and those that needs to be improved. The eight requirements for GAP corn certification were evaluated that included: farm location, farm environment, farm structure and facility maintenance, pre-harvesting practices, harvesting practices, post-harvesting practices, safety and precautions, and farm management.

OBJECTIVES

This study aimed to determine the demographic profile of the respondents, the level of the respondents' awareness in GAP corn certification requirements, and the extent of compliance in GAP corn certification.

METHODOLOGY

The study was conducted in 2019 in the four corn cluster municipalities (Bagabag, Diadi, Quezon and Villaverde) of Nueva Vizcaya. Simple random sampling was used to identify the 160 respondents. Descriptive statistics such as frequency counts, mean, and percentages was used in describing the demographic characteristics of the respondents. A four-point Likert-type scale was used to analyze the level of awareness and extent of compliance. Pearson's *r* was used in measuring the significant relationships between the variables in the study.

Instruments for data collection included: survey questionnaires and key informants' interview of Farmer Led Extensionists (FLEs) and Agricultural Extension Workers (AEWs). The structured survey questionnaire included open-ended and categorized questions.

RESULTS AND DISCUSSION

Demographic Characteristics of Corn Farmers

The result revealed that 50% are male and 50% are female. It can be noted that more females are now involved in corn farming and in the agricultural industry as a whole. The mean age is 52 years old, the youngest is 25 years old and the oldest is 80 years old. It can be deduced that there are older corn farmers because younger people nowadays prefer nonfarm careers. In the Cagayan Valley Region, the average age of corn farmers is 51 years old (PSA, 2014).

The study shows that the respondents are mostly high school level or graduates with 51.90%, college (25.1%) and vocational/technical education (5.6%). It can be inferred that the corn farmers are better educated when compared to the provincial statistics wherein high school is 35.75%, college (19.40%) and vocational (3.40%) (PSA, 2014), in effect they are more open in adopting new technologies and practices in farming. They also understand the consequences of conforming to sustainable agricultural practices for land-use and production efficiency, global warming potential, economic viability, conservation of biodiversity, waste minimization and recycling, farmer and community well-being, animal welfare, and the capacity to meet food sufficiency long into the future. Education also allows a farmer to share his farming experiences to other farmers.

The average area farmed is 1.93 hectares, majority (58.2%) of the corn farmers surveyed have 1.0 - 2.9 hectares. The result signifies that the size of cultivated land and average land productivity could strongly affect farm revenues and, consequently, investments. This explains the ability of farmers to diversify in farming, smaller land area tends to lean more on monocropping which is discouraged in GAP since it proliferates pests and diseases and depletes soil fertility while larger farmlands could diversify not only as an approach to prevent pests/diseases and soil fertility

depletion but to increase revenue as well. The increase in revenues enable the farmers to establish the needed facilities and structures in GAP farming.

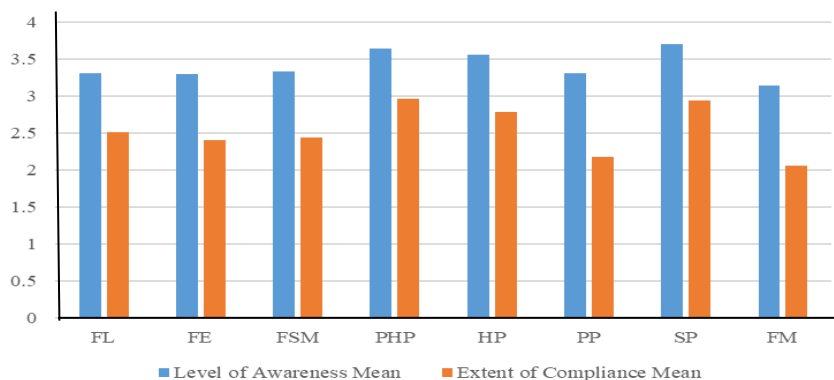
The average number of years in corn farming is 20. Most respondents had 10-29 years (56.5%) experience in corn farming, 24.5% had more than 30 years and 19.5% with less than 10 years. The respondents' minimum number of years in corn farming is 5 and the maximum is 60 years of experience. It can be noted that the respondents are experienced corn farmers. Extensive experience in corn farming helps the farmers to determine the merits of adopting new technologies based on their knowledge gained through years of corn farming. This aided them in decision-making for adopting GAP, in addition it boosts their confidence to share their experiences and facilitate the spread of new technologies like GAP. This is consistent with the national and regional statistics wherein (BAS, 2011) reported that corn farmers in the country had an average of 22 years of farming experience.

More than eighty percent (86.7%) are members of farmers' organization, cooperatives with 65.6% and other organizations with 54.4%. Membership to farmers' organizations, cooperatives and other organizations in the community help the farmers to unify their efforts towards achievement of their common goals especially in lobbying for government and other agencies' support and services in training, facilities and machineries, loans and other agricultural assistance. Cooperatives is the government vehicle in granting farmers loans. It also extended seed, fertilizer and agrichemical loans with agreeable payment schemes. It is through these organizations that small farmers band together to convey issues and concerns through their representatives (e.g., Municipal Agricultural and Fishery Council) and avail of assistance.

Respondents' participation to GAP-related trainings such as integrated pest management (IPM) like proper spraying and disposal of used herbicides, how to make organic pesticides from fruit and plant juices, pest surveillance, etc. has high attendance with 96.3%, followed by integrated crop management with 74.4% and other trainings with 38.1%. These related trainings support the implementation of GAP by reinforcing it through activities and demo farms. It will also increase the farmers' self-reliance and confidence in adopting GAP by expounding their training to encompass technologies that is important in sustainable agriculture. These practices help to improve environmental and ecological diversity as well as economic condition towards GAP adoption.

Awareness and Compliance in GAP Corn

Fig. 1 illustrates the comparison of means for the respondents' level of awareness and extent of compliance for the eight GAP corn requirements.



FL – Farm location, FE – Farm environment, FSM – Farm structure and maintenance, PHP – Pre-harvesting practices, HP – Harvesting practices, PP – Post-harvest practices, SP – Safety and precaution, FM – Farm management

Fig. 1 Comparison of means for the respondents' level of awareness and extent of compliance to GAP corn

Farm location has high awareness denoted by an average mean of 3.31 on the suitability of the production area and its surrounding farms for agricultural use. They have to trace the history of the land use whether it is being used for other purposes other than agriculture such as landfill to identify possible potential hazards specifically chemical (heavy metals) and physical hazards (broken glass, plastics, rubber, etc.) as part of the requirement. However, the respondents are moderately aware on how to identify ways to prevent the potential hazards. The result implies that the respondents are highly aware of the requirements and fully understood the importance of tracing the history and land use pattern of their farm. These requirements were thoroughly discussed during the GAP training conducted by the Agricultural Training Institute (ATI), Department of Agriculture (DA) and Local Government Units (LGUs). Compliance is moderate with an average mean of 2.51 for farm location since all of the corn farms were established not for other purposes but for crop production only and the potential hazards identified is the excessive use of agrichemicals and natural calamities such as flooding and drought. The slight compliance for mitigating measures is attributed to their lack of documentation or records concerning the potential hazards in their farms.

Respondents' awareness on farm environment was high with an average mean of 3.30. The respondents were highly aware that the production area, post-harvest and storage area should be kept clean at all times to avoid contamination. Likewise with the importance of crop rotation to avoid soil deterioration due to monocropping especially planting of nutrient enriching plants like peas, peanuts, beans and other leguminous crops and availability of water source or irrigation to avoid plant stress. It is only soil analysis that has moderate awareness, this might be due to absence of soil laboratory in the province to cater the needs of the corn farmers. The farmers have to submit soil samples through the LGUs to be brought to the soil laboratory at the neighboring provinces in Isabela or Cagayan. The respondents stated that the release of the soil analysis result as basis for fertilizer application was delayed wherein the crops was already harvested but the result is not released yet. The AEWs also encourage the use of convergence approach such as integrated farming for the integration of other crops and livestock in corn farming as alternative source of income. The compliance for farm environment is slight with an average mean of 2.40 for field sanitation practices, soil nutrient status analysis for appropriate fertilizer recommendation, soil mapping for crop rotation and production plans and locating water sources. Soil analysis should be done every two years and carried out by accredited laboratory. The slight compliance for certification requirements with regards to farm environment can be attributed to their non-adoption of strict field sanitation practices, soil analysis, and soil mapping.

The respondents were highly aware that farm structures and facilities should be maintained with an average mean of 3.33. Structures such as warehouse for the corn produce, storeroom for fertilizer, pesticide and other farm supplies and materials including protection shed of farm machineries should be appropriately designed and constructed in a reasonable distance from one another to lessen contamination. Likewise, farm structures, facilities and equipment should always be kept clean and in good condition for optimal operations. They were also highly aware that sewage, waste disposal and drainage system should be appropriately located and constructed to minimize the risk of contaminating the production area and water supply with chemical hazards. The farmers claimed that GAP is good since it safeguards health, and the proper storage of agrichemicals such as insecticides, pesticides and fungicides makes it easier to locate when needed. Display of farm code and availability of medicine kit in the farm is moderate. It is imperative that a fully equipped first aid box with all the necessary items is placed prominently in the farm. Farm structure and facility maintenance has slight compliance with an average mean of 2.44. The respondents' reason for slight compliance is the lack of finances to construct farm structures such as storage for tools and machineries though there is no prescribed size for structures as long as it is safe for farm tools and materials and properly labeled. The respondents stressed that they are compliant in GAP especially in farming practices but lack the financial capability to establish the needed structures and toilets required in GAP corn certification that is the reason for non-certification.

The result for the pre-harvest practices has high awareness with an average mean of 3.64 that includes weed control measures through proper land preparation to ensure healthy and uniform

plant growth; planting and seed materials such as use of high yielding varieties that are adaptable to the locality and following the recommended planting distance and seeding rate; proper handling and use of agrichemicals such that applicators should be trained and wear protective gear when handling and spraying, agrichemicals should be properly labeled and stored and proper disposal of empty container, and strict observance of pre-harvest intervals; fertilizer management such as use of fully decomposed organic materials, fertilizer application should be based on soil analysis, proper storage to prevent contamination due to leaching, runoff or wind drift and records of fertilizer sources and application; insect pest and disease management during flowering to maturation stage and prevention of aflatoxin contamination; other cultural management practices such as maintenance of the recommended row and plant spacing to avoid overcrowding and regular monitoring at all crop stages to provide measures to problems that may arise. While compliance is moderate with an average mean of 2.96, the pre-harvesting practice were adequately implemented and complied by the respondents due to their extensive experience in corn production.

Harvesting practices includes harvesting of fully matured corn in the shortest possible time, the use of clean mats and other suitable underlays to prevent damage and contamination of corn ears and remove corn ears that show visible signs of insect or microbial damage. The respondents have high awareness with an average mean of 3.56 but moderately complied with an average mean of 2.78. Following the recommended harvesting practices has high compliance but sorting has slight compliance. Sorting out and discarding corn ears with visible damage is not followed by the respondents because they sell their harvest immediately to buyers upon harvesting.

Post-harvesting practices has high awareness with an average mean of 3.31. This includes hauling should be done immediately after harvest and facilities for hauling should be clean and dry; immediate drying of corn grains to reduce the moisture content; avoid grain moisture accumulation during transport by using an appropriate covering for the container, proper stacking inside the transport vehicle and protection against pests; storing area should have good ventilation, prevent entry of insects, birds and rodents and maintain the recommended moisture content to minimize aflatoxin contamination and conformity to the principle of first-in-first-out. The respondents asserted that though they are aware of the ideal moisture content of the corn to avoid aflatoxin but they do not have the instrument for testing it. Post-harvesting practices has slight compliance with an average mean of 2.18. This might be due to the fact that farmers sell their yellow corn directly upon harvest and no longer follow post-harvesting practices while white corn also referred to as green corn are sold by contract when it is matured for cooking and eating. The key informant revealed that GAP evaluation for certification in post-harvesting is done by testing for aflatoxin which is accomplished by getting 5 kilos sample from the harvested seeds. The dried seeds was brought to the laboratory at DA-Cagayan Valley Integrated Agricultural Laboratory (DA-CVIAL) for the said test.

With regards to safety and precautions, all the variables were rated to have high awareness with an average mean of 3.70. This includes wearing of appropriate clothing and protective gears in production and post production activities and training of farm workers to follow the recommended personal hygiene and sanitary practices. The respondents agreed that safety gears should be worn to avoid exposure to chemical hazards as well as training and supervising farm workers in the proper use of agrichemicals and sanitary procedures. It is a major compliance criterion that pesticide application protective gear must be present in the farm at all times. The equipment must be kept clean and functional, and there must be documentation that shows that farm workers have been trained to use the protective gear correctly. Compliance on safety and precautions was rated to be moderate with an average mean of 2.94. The respondents are moderately compliant with safety and precautions which implies that though they are aware of the consequences of mishandling agrichemicals but some farmers still do not strictly follow the recommended safety and precaution practices.

Respondents has high awareness on farm management with an average mean of 3.14. It includes keeping of farm and staff records and traceability. Farm records should be updated using the DA pro-forma record system of GAP corn and should be kept up to two years. (PNS, 2017) explained that new farm applying for certification must have at least 3 months of farm records which should be presented during audit, hence, someone should be designated as in-charge to deal

with matters associated with GAP corn certification. Likewise with records of farm workers and their trainings should be maintained. The respondents claimed that though there is a pro-forma record system but they also use a simplified record system that they could easily understand. They use record book to log in farm activities with the corresponding expenses like cost of inputs and labor. In traceability, produce leaving the farm must be traceable to the farms, thus records must also be maintained. The respondents insisted that the corn buyers can trace back the produce to their farms since they know their sources or suppliers of corn. Compliance was slight with an average mean of 2.06. Farm records has moderate compliance that includes designating in-charge to deal with matters associated with GAP corn certification like copies of laboratory analysis and certificates that verify compliance with the DA regulations. The respondents claimed that maintaining the pro-forma farm records from DA is complicated and time consuming, hence, they improvised and ask assistance from family members and AEWs in accomplishing the farm records issued by DA. Maintaining of staff records has slight compliance and traceability was low which suggests that the respondents are not compliant with these particular criteria.

The overall mean for GAP corn awareness was denoted by the mean value of 3.42, which is qualitatively described to have 76-100% awareness of the requirements in the GAP corn. While the overall mean on the extent of compliance is indicated by a mean value of 2.54 which is qualitatively described to have 51-75% compliance signifying that awareness is 25% higher than the respondents' compliance.

In the correlation analysis in Table 1, sex, highest educational attainment, and trainings are significantly correlated to the respondents' awareness in farm environment, pre-harvesting and harvesting practices at 5% level of significance. The respondents' awareness in GAP corn in terms of farm environment ($r = 0.174$) and pre-harvesting practices ($r = 0.176$) positively correlated with sex. It indicates that more involvement of both men and women in corn farming spell increased awareness in farm environment that includes cleanliness to avoid contamination, crop rotation, and availability of irrigation; and pre-harvesting practices such as weed control measures, planting and seed materials used, proper use of pesticides and other agrochemicals, fertilizer, insect and pest management and other cultural management practices. The respondents' awareness in terms of farm environment ($r = 0.157$) and pre-harvesting practices ($r = 0.163$) are significantly correlated with the respondents' highest educational attainment. The result signifies that the respondents with higher educational attainment have higher understanding of the environmental effect and pre-harvesting practices in GAP corn. This further implies that the respondents' education is important in their awareness and adoption of GAP corn.

Table 1 Relationship between the demographic profile and level of awareness in GAP corn

Demographic profile	Level of awareness in gap corn							
	FL	FE	FSM	PHP	HP	PP	SP	FM
Age	.006	-.046	-.043	-.048	-.045	-.032	-.039	-.039
Sex	.059	.174*	.130	.176*	.151	.134	.143	.143
Highest educational attainment	-.064	.157*	.081	.163*	.117	.076	.096	.096
Land area for corn farming	.083	.097	.096	.097	.097	.097	.097	.097
Number of years in corn farming	.121	.087	.066	.086	.075	.093	.085	.085
Membership in farmer's organization	.021	.022	.008	.022	.015	.018	.017	.017
Membership in cooperatives	.032	.019	.008	.018	.012	.019	.016	.016
GAP trainings	.090	.175	.123	.178	.147	.141	.144	.144
Other trainings	.080	.348**	.203	.354**	.267*	.231	.249	.249

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed)

FL – Farm location, FE – Farm environment, FSM – Farm structure and maintenance, PHP – Pre-harvesting practices, HP – Harvesting practices, PP – Post-harvest practices, SP – Safety and precaution, FM – Farm management

Respondents' awareness in farm environment ($r = 0.348$) and pre-harvesting practices ($r = 0.354$) are highly significant when correlated with trainings while significant in terms of harvesting practices ($r = 0.267$). The positive correlation implies that more trainings conducted to the corn farmers magnified their awareness on farm environment, pre-harvesting and harvesting practices. It further implies that generally, participation to trainings like proper storage of corn, how to make feeds and organic fertilizers, field days, and production of other crops and animal raising increased the farmers' knowledge and awareness on the effect of GAPs to corn farming especially in the environment, pre-harvesting and harvesting practices. Environmental protection supports sustainable agriculture while pre-harvesting and harvesting practices are important in the assurance of food safety. This indicates that trainings conducted in support to GAP is important to the respondents' awareness. Furthermore, the respondents were also trained on integrated farming and other alternative sources of income such as fishery, poultry and livestock and other crops like vegetables to supplement family income since corn takes more than three months to be harvested. Likewise, Azam and Banumathi (2015) denoted that educational attainment, age and gender of the farmers has positively motivated them to move towards GAP farming.

The correlation analysis in Table 2, finds no significant relationship between the demographic profile and extent of compliance in GAP corn. The result indicates that demographic characteristics has no effect in the farmers' compliance to GAP corn. This might be the reason for the very low (1.78%) GAP certification of corn farms in Nueva Vizcaya since all the requirements for certification should be complied 100%, partial compliance will be deferred. The respondents affirmed that GAP corn compliance is labor intensive since it needs more labor to comply with the criteria such as establishment of fences or barriers to prevent entry of animals and other predators, pest and diseases surveillance and strict implementation of field sanitation practices. The respondents claimed that they have 75-85% compliance since most of the farming practices were complied. It is the establishment of structures that they lacked. Adding that even if the farm will not be certified, they still need to maintain good agricultural practices always for environmental protection and health reasons. This is affirmed by the study of Ganpat et al. (2014) that compliance on GAPs among smallholder farmers was low.

Table 2 Relationship between the demographic profile and extent of compliance in GAP corn

Demographic profile	Extent of compliance in GAP corn							
	FL	FE	FSM	PHP	HP	PP	SP	FM
Age	-.039	-.037	-.038	-.039	-.038	-.038	-.038	-.038
Sex	.143	.141	.142	.142	.142	.142	.142	.142
Highest educational attainment	.096	.091	.095	.095	.095	.094	.095	.095
Land area for corn farming	.097	.097	.097	.097	.097	.097	.097	.097
Number of years in corn farming	.085	.087	.086	.085	.085	.086	.086	.086
Membership in farmer's organization	.017	.017	.017	.017	.017	.017	.017	.017
Membership in cooperatives	.016	.017	.016	.016	.016	.016	.016	.016
GAP trainings	.144	.144	.144	.144	.144	.144	.144	.144
Other trainings	.249	.245	.248	.248	.248	.248	.248	.248

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed)

CONCLUSION

Demographic characteristics of the corn farmers in Nueva Vizcaya, Philippines comprised men and women active involvement in farming, older farmers with a mean age of 52 years, most have formal education with 51.90% high school level or graduates, majority (58.2%) are small farm holders with an average land area of 1.93 hectares, more experience in farming with an average of

20 years and has membership in farmers organization (86.7%) and cooperatives (65.6%) and participation to GAP and GAP-related trainings with 96.3%. These characteristics towed their level of awareness which is high or qualitatively described to have 76-100% awareness of the GAP requirements while their compliance is moderate which is 51-75% compliant to GAP certification requirements that subsequently deferred their application for GAP certification. Generally, the corn farmers adopted GAPs especially in farm environment, farming practices for pre-harvesting and harvesting but their compliance to records of potential hazards in farm location, establishment of farm structures, post-handling practices, safety and precaution practices, documentation/recording and traceability in farm management needs to be improved.

ACKNOWLEDGMENTS

The author is grateful to the Commission on Higher Education (CHED) for the study grant and to the Nueva Vizcaya State University for the indorsement.

REFERENCES

- Agricultural Training Institute (ATI). 2013. Hand-outs on the updated guidelines on GAP certification for crops superseding. Administrative Circular, No. 10, series of 2013.
- Azam, M.S. and Banumathi, M. 2015. The role of demographic factors in adopting organic farming, A logistic model approach. *International Journal of Advanced Research*, 3 (8), 713-720, Retrieved http://www.journalijar.com/uploads/560_IJAR-6817.pdf
- Bureau of Agricultural Statistics (BAS). 2011. Costs and returns of corn production. Quezon City Philippines.
- Ganpat, W., Badrie, N., Walter, S., Roberts, L., Nandlal, J. and Smith, N. 2014. Compliance with good agricultural practices (GAPs) by state-registered and non-registered vegetable farmers in Trinidad, West Indies. *Food Security*, 6, 61-69, Retrieved from DOI <https://doi.org/10.1007/s12571-013-0322-4>
- Official Gazette of the Philippines. 2013. Republic Act 10611, An act for food safety. Retrieved from <https://www.officialgazette.gov.ph/2013/08/23/republic-act-no-10611/>
- Philippine National Standards (PNS). 2017. Revised code of good agricultural practices (GAP) for corn. PNS/BAFPS. Retrieved from https://bafs.da.gov.ph/bafs_admin/admin_page/pns_file/PNS%20BAFS%202020%202018%20GAP%20Corn.pdf
- Philippine Statistics Authority (PSA). 2014. 2013 costs and returns of corn production. Quezon City Philippines. Retrieved from <https://psa.gov.ph/site/default/files/crscorn20130>



Evaluation of Sediment Trapping Capacity by Geotextile for Erosion Control

SARVESH MASKEY

Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

TAKANORI KANEKO

Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

HIROMU OKAZAWA*

Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

Email: h1okazaw@nodai.ac.jp

ANTONIO PEREZ FUENTES

Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

SACHIKO WATANABE

Maeda Road Construction Co. Ltd., Tokyo, Japan

KAZUHIRO TAZAKI

Maeda Road Construction Co. Ltd., Tokyo, Japan

TAKAHIRO SASAKI

Maeda Road Construction Co. Ltd., Tokyo, Japan

Received 30 January 2022 Accepted 18 July 2022 (*Corresponding Author)

Abstract Heavy precipitation events induce sediment transport resulting in soil loss, aggravating erosion. Geotextile for erosion control, offers environmentally friendly benefits and have lower costs than other physical structures. Recently, there has been interest in high performance and multifunctional geotextiles. In this study, evaluation was made to investigate the capacity of geotextile in sediment trapping. A runoff experiment was conducted, using a runoff plot using two types of geotextiles, having dimensions of 100 and 10 cm length and breadth respectively. Slope for the runoff plot was created at 0.859 degrees. Four treatments, for each geotextile were made. The treatments were, 1) no folds, 2) folds for 25 cm of the runoff plot, 3) folds for 50 cm of runoff plot, 4) folds for 100 cm of the runoff plot. Muddy water suspension having Suspended Solid (SS) of 25000 mg/L was discharged on the treatments. SS of runoff and infiltrated suspension were analyzed. According to the results, both geotextiles were effective in sediment trapping. For Sample A, SS decreased by 88.1%, 97.16%, 99.14% and 99.15% in no folds, 25 cm fold, 50 cm fold and 100 cm fold treatment respectively from the initial SS of the muddy water suspension. Whereas, for Sample B, SS decreased by 87.3%, 91.87%, 98.74% and 98.34% in no folds, 25 cm fold, 50 cm fold and 100 cm fold treatments respectively. Additionally, SS significantly decreased in folded treatments for both geotextiles. Accordingly, it was established that geotextile can function for erosion controlling with increase in folds. However, further research is required to understand the intensity of discharge on geotextiles for sediment trapping capacity for future applications.

Keywords geotextile, sediment trap, erosion control, suspended solid

INTRODUCTION

Precipitation and heavy precipitation events are amongst the most significant weather parameters inducing sediment transport aggravating soil erosion. Soil erosion is one of the biggest concerns of land's surface as it has many impacts in agriculture, engineering, and construction industries. Various physical measures have been developed and used for controlling soil erosion. Geotextiles are permeable fabrics which functions in separation, filtration, drainage, reinforcement, stabilization, barrier, and erosion protection (Agrawal, 2011). Geotextiles helps in reducing soil erosion by reducing runoff velocity (Balasubramanian, 2017). Physical erosion measures such as gabions, riprap, drop structures, chutes, check dams etc., which works on principal of reducing runoff velocity (Balasubramanian, 2017) are expensive to construct and maintain, also it takes considerable time for construction. However, geotextiles are environmentally friendly, cost-effective measure and are easy to install. Geotextiles, like mulches control soil erosion by imitating the salient properties of vegetation (Rickson, 1990). Geotextiles can improve the surface microclimate, retains soil moisture which promotes seed germination and vegetation growth (Bergado and Soralump, 1999). Additionally, geotextiles can control soil erosion by affecting the quantity and volume of runoff that detaches and transports the sediments. The erosion control geotextiles are directly applied on the exposed surface which provides an immediate protection against soil erosion by reducing flow velocity and detaching forces by impact of raindrops (GEO, 2011). In recent years, there has been interest in high performance and multifunction geotextiles. Therefore, in this study, two geotextiles which functions in inhibiting weed growth were subjected to determine its sediment trapping capacity potential for erosion control.

MATERIALS AND METHOD

Characteristics of Geotextile Used

The geotextiles used in this study are made up of polyester fibers having high tensile strength, elongation capacity, water and air permeability and maintains the natural conditions of the soil. As can be observed from the Table 1, Sample A has lower mass, thickness, tensile strength, and horizontal elongation compared to Sample B. Whereas, water permeability and light resistance for both the geotextiles are similar.

Table 1 Characteristics of geotextile tested

Parameters	Sample A	Sample B
Mass (g/m ²)	130	300
Thickness (mm)	0.5	1.0
Tensile strength (N/5 cm)		
Vertically	343	882
Horizontally	196	686
Elongation (%)		
Vertically	32.0	35.0
Horizontally	28.0	40.0
Water permeability (cm/sec)	1.0×10 ⁻² above	1.0×10 ⁻² above
Light resistance (%)	9.0	9.0

Note: Data obtained from Toyobo Corp., Japan

Experiment Settings and Conditions

In this research, sediment trapping capacity of two geotextiles Sample A and Sample B were evaluated. For this, runoff experiment was conducted using a runoff plot of 100 cm and 10 cm length and breadth respectively having a slope gradient of 0.859 degrees (Fig. 1).

Three different treatments for each geotextile were made as shown in Table 2: 1) Control, 2) Folds for 25 cm of the plot, 3) Folds for 50 cm of the plot, 4) Folds for 100 cm of the plot. This was

done to see the effectiveness of having folds on reducing the sediment flow. Runoff experiment on the geotextile was conducted using 500 ml of muddy water suspension having Suspended Solid (SS) value of 25000 mg/L. The muddy suspension water was poured at inlet in 10 seconds. The runoff and percolated suspension were collected, and SS was analyzed between geotextiles and their groups.

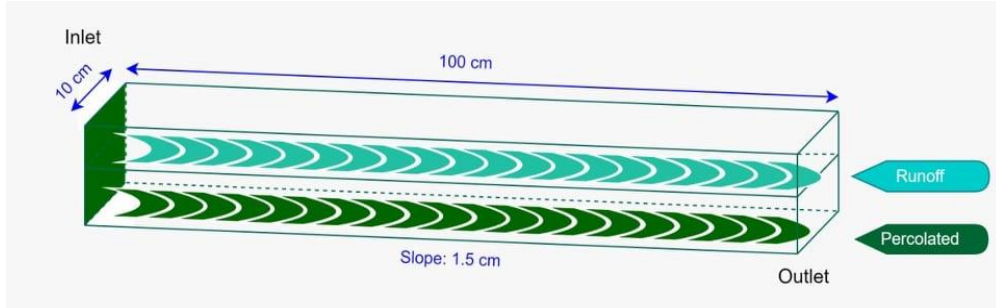


Fig. 1 Schematic diagram of runoff plot

Table 2 Treatments for the geotextiles used for this research

Sample A	Sample B
1. Control (plain surface)	Control (plain surface)
2. Folds for 25 cm of the plot	Folds for 25 cm of the plot
3. Folds for 50 cm of the plot	Folds for 50 cm of the plot
4. Folds for 100 cm of the plot	Folds for 100 cm of the plot

Note: Each fold was made of 2cm length

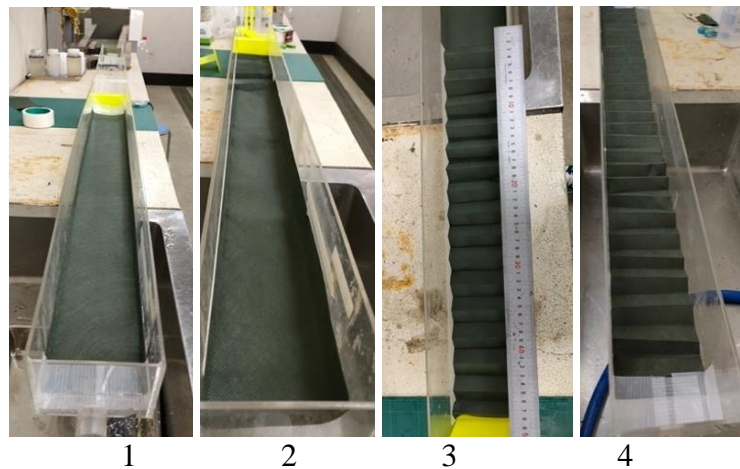


Fig. 2 Treatments made for runoff experiment

Determination of Suspended Solid and Soil Loss Reduction Effectiveness

Suspended Solid of the runoff was analyzed using glass fiber filter method. In this method a measured volume of sample (less than 1L) is passed through pre-weighted filter paper which is dried at 104°C ± 1. After drying, the filter paper is weighed, and SS was calculated using Equation 1.

$$SS \text{ mg/L} = \frac{\text{Weight (final)} - \text{Weight (initial)} \times 1000}{\text{Volume of sample (mL)}} \quad \text{Eq. 1}$$

To see the difference of soil loss created by runoff in each treatment with those of the control plots, ratios between treatments and control (Ogbobe et al., 1998) and effectiveness indexes (Sutherland, 1998) was used. For this, in this experiment, soil loss reduction effectiveness (SLRE, %) was used (Sutherland, 1998), which was calculated using Equation 2.

$$SLRE_t = \frac{SL_c - SL_t}{SL_c} \times 100 \tag{Eq. 2}$$

Where, *t*, *c*, *SL* are treatment, control, and soil loss respectively. A positive effectiveness indicates geotextile reduces soil loss, whereas a negative effectiveness indicates geotextiles produces more soil loss. In this experiment the value of SS is used for soil loss.

RESULTS AND DISCUSSION

Comparison of Runoff SS between Geotextiles and Sediment Trapping Capacity

The sediment trapping capacity of the geotextiles were evaluated by the difference in initial SS of muddy water suspension with the SS of runoff for each geotextile. Fig. 3 shows the comparisons between the treatments. As can be observed from Fig. 3, all the treatments were effective in reducing runoff SS. Additionally, it was observed that treatments with folds could reduce SS significantly compared to control. However, no significant difference was seen between the geotextiles for each treatment. Rickson, 1992, states that the random roughness of fibers contributes to decrease in runoff velocities, thereby reducing the transport capacity and leading to deposition of particles within the geotextile fibers. It can be argued that both geotextiles may have changed the hydraulic flow properties, trapping the sediments.

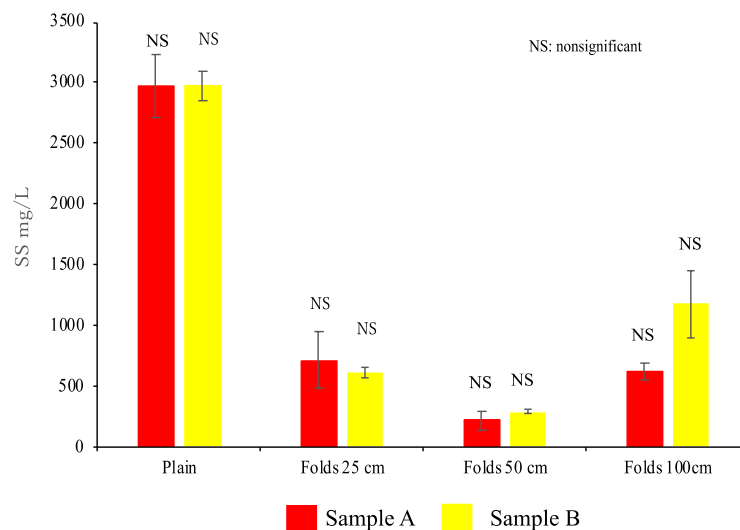


Fig. 3 Comparison of SS of runoff suspension between geotextile treatments

Comparison of Runoff and Percolated SS between in Sample A

The result for runoff SS and percolated SS is shown in Figs. 4 and 5 respectively for Sample A. As can be observed from the results, SS for all the treatments including control decreased significantly. In addition, it was clarified that having folds in the treatment reduced SS. This can be explained as with increase in folds, the kinetic energy of the runoff decreases due to obstacles and friction. Further, it was observed during the experiment that, muddy suspensions got trapped in the folds. This deposited the sediments in the folds, significantly reducing the runoff SS. In given condition of the experiment, folds 50 and folds 100 were more effective compared to 25 cm fold. It was also

clarified that Sample A had filtration function. The SS of percolated suspension had very low SS for all the treatments.

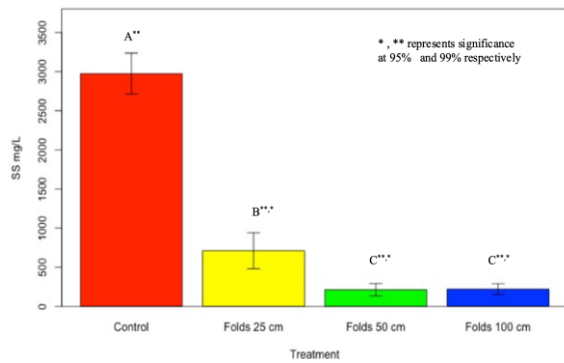


Fig. 4 Difference SS of runoff suspension for Sample A geotextile treatments

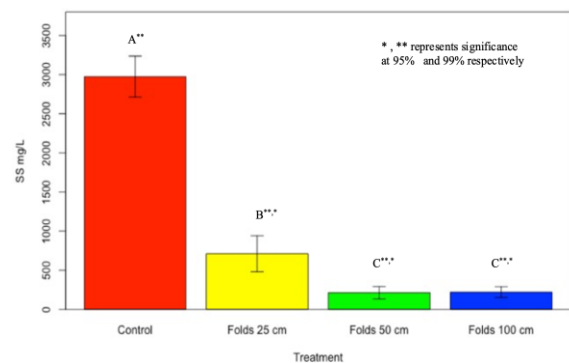


Fig. 5 Difference in SS percolated suspension for Sample B geotextile treatments

Comparison of Runoff and Percolated SS between in Sample B

The results for runoff and percolated SS in geotextile Sample B showed similar results to that of Sample A. The surface runoff SS decreased significantly compared to initial muddy water suspension in all the treatments. As can be observed from Fig. 6, having folds in the textile increased sediment trapping capacity decreasing runoff SS. Similar arguments can be made for the sediment trapping capacity as made for geotextile Sample A. Figure 7 shows the result of percolated SS for geotextile Sample B. Unlike Sample A, percolated SS was not observed in this geotextile. Geotextile Sample B is 0.5 mm thicker than geotextile Sample A (Table 1), which made the runoff faster, resulting in less time for saturation of geotextile and percolation. On the other hand, in folds the suspension was trapped, resulting in percolation. The percolated SS for this geotextile was also very low showing filtration function.

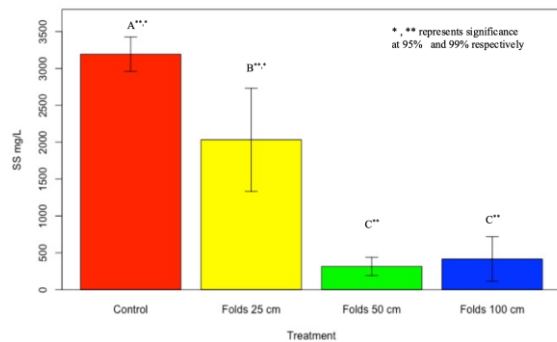


Fig. 6 Difference SS of runoff suspension Sample B geotextile treatments

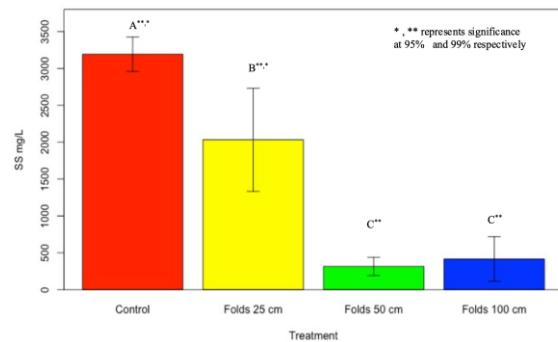


Fig. 7 Difference in SS percolated suspension for Sample B geotextile treatments

Suspended Solid Reduction (%) and Soil Loss Reduction Effectiveness (SLRE, %)

Table 3 shows the SS runoff decrease percent compared to SS of initial muddy water suspension. For Sample A, SS decreased by 88.1%, 97.16%, 99.14% and 99.15% in no folds, 25 cm fold, 50 cm fold and 100 cm fold treatment respectively from the initial SS of the muddy water suspension. Whereas, for geotextile Sample B, SS decreased by 87.3%, 91.87%, 98.74% and 98.34% in no folds, 25 cm fold, 50 cm fold and 100 cm fold treatments respectively. SLRE (%) had positive effectiveness, showing folds in geotextiles was effective in reducing soil loss for both the geotextiles.

Table 3 Suspended solid reduction (%) and SLRE (%)

Treatment	Sample A			Sample B		
	SS (mg/L)	% Decrease	SLRE (%)	SS (mg/L)	% Decrease	SLRE (%)
Initial sample	25000			25000		
Control	2974	88.1		3193	87.23	
25 cm folds	711	97.16	76.09	2032	91.87	36.36
50 cm folds	213	99.14	97.31	315	98.74	90.13
100 cm folds	221	99.15	97.67	416	98.34	86.97

CONCLUSION

A runoff experiment was conducted to examine sediment trapping capacity of two geotextiles. The results showed that both geotextiles significantly decreased the runoff and percolated SS. It was also observed that having folds in the geotextile increased sediment trapping capacity. In addition, soil loss reduction efficiency had high positive values for indicating soil loss reduction. Soil loss reduction efficiency increased with increase in folds in the geotextile. With outcomes of this study, it can be concluded that geotextiles A and B had sediment trapping capacity and can function in reducing soil erosion. However, for future application, further studies are required with varying runoff intensity and slope for sediment trapping capacity.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Maeda Road Construction Co. Limited, Tokyo, Japan for providing the geotextiles used in this study.

REFERENCES

- Agrawal, B.J. 2011. Geotextile, Its application to civil engineering, Overview. In proceedings of the National Conference on Recent Trends in Engineering and Technology, 1-6, Retrieved from <https://bvmengineering.ac.in/misc/docs/published-20papers/civilstruct/struct/101052.pdf>
- Balasubramanian, A. 2017. Methods of controlling soil erosion. Report No. 2, University of Mysore, India, Retrieved from DOI 10.13140/RG.2.2.22542.97609
- Bergado, D.T. and Soralump, S. 2003. Geosynthetics for erosion control and preservation of environment. International Symposium and Short Course on Soil/Ground Improvement and Geosynthetics in Waste Containment Structures, 2003, AIT, Thailand, Retrieved from https://www.researchgate.net/publication/237834251_GEOSYNTHETICS_FOR_EROSION_CONTROL_AND_PRESERVATION_OF_ENVIRONMENT
- Geotechnical Engineering Office (GEO). 2011. Technical guidelines on landscape treatment for slopes. GEO Publication No. 1, Retrieved from https://cedd.gov.hk/filemanager/eng/content_151/ep1_2011.pdf
- Ogboobe, O., Essien, K.S. and Adebayo, A. 1998. A study of biodegradable geotextiles used for erosion control. *Geosynthetics International*, 5 (5), 545-553, Retrieved from DOI <https://doi.org/10.1680/gein.5.0131>
- Rickson, R.J. 1990. The role of simulated vegetation in soil erosion control. In Thornes, J.B. (Ed.), *Vegetation and Erosion, Processes and Environments*, 99-112, Wiley, Chichester, USA.
- Rickson, R.J. and Vella, P. 1992. The application of geotextiles in the protection of grassed waterways in erosion, conservation and small-scale farming. In Hurni, H. and Tato, K. (Eds.), 415-421, *Geographia Bernesia*, Bern, Switzerland.
- Sutherland, R.A. 1999. Rolled erosion control systems for hillslope surface protection, A critical review, synthesis and analysis of available data, I. background and formative years. *Land Degradation and Development*, 9 (6), 465-486, Retrieved from DOI [https://doi.org/10.1002/\(SICI\)1099-145X\(199811/12\)9:6<487::AID-LDR312>3.0.CO;2-U](https://doi.org/10.1002/(SICI)1099-145X(199811/12)9:6<487::AID-LDR312>3.0.CO;2-U)



Estimation of Long-term River Discharge in Forested Watershed in Snowy Region by SWAT

SHOTARO KIKUCHI

Graduate School of Agriculture, Tokyo University of Agriculture, Japan

HIROMU OKAZAWA*

Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

Email: h1okazaw@nodai.ac.jp

SARVESH MASKEY

Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

SERGIO AZAEL MAY CUEVAS

Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

MAKOTO OBA

*Department of Design for Social System and Living Environment,
Tohoku Institute of Thechnology, Japan*

SHOGO NAKAMURA

*Fukushima Regional Collaborative Research Center,
National Institute for Environmental Studies, Japan*

SEIJI HAYASHI

*Fukushima Regional Collaborative Research Center,
National Institute for Environmental Studies, Japan*

Received 31 January 2022 Accepted 18 July 2022 (*Corresponding Author)

Abstract Utilizing a hydrological model for analyzing the hydrological cycle throughout a river basin is an effective method to assess the impacts of climate change on water resource management, flood control, and agriculture. Although there are various hydrological models developed, in this study, Soil and Water Assessment Tool plus (SWAT+) is used as it is widely used and predicts the impacts of land use management in watershed management. SWAT+ is a complex quasi-physically based water quality model relying on numerous input files and parameters, thus this poses a great challenge when attempting to set up the model manually, and there is a lack of information regarding the validation of SWAT+'s of performance for snow accumulation and melting processes. The objective of this study is to estimate long-term streamflow in forested watershed in snowy region using SWAT+, and to verify the accuracy of the estimation and to confirm the improvement of the accuracy by adjusting parameters. In order to improve the accuracy of simulation, “the saturated hydraulic conductivity of soil layer” and “the available water capacity of soil layer” were adjusted for parameter of soil moisture content, moreover, we adjusted parameter of temperature of “snowfall” and “snowmelt”. Finally, “the time of lateral flow travel” which is difficult to measure was calibrated using the auto-calibration of SWAT+. As the results, it was difficult to achieve high accuracy in predicting river discharge with the default parameters of SWAT+, but some months (May-Oct) could be accurately predicted after adjusting parameters using measured data and conducting the auto-calibration. On the other hand, simulations during snowfall and snowmelt term (Dec-Mar) were less accurate and need to set more detailed conditions.

Keywords SWAT, long-term river discharge, snowmelt, runoff, prediction,

INTRODUCTION

With rising temperatures by climate change will threatens to disturb this balance by altering the fraction of precipitation falling as snow and the timing of snowmelt, which may have profound effects on food production (Qin et al., 2020). Utilizing a hydrological model for analyzing the hydrological cycle throughout a river basin is an effective method to assess the impacts of climate change on water resource management, flood control, and agriculture. SWAT (Soil and Water Assessment Tool) developed by USDA-ARS is a hydrological cycle model that has been used worldwide for more than 20 years (Williams et al., 2008). In order to face present and future challenges in SWAT code has undergone major modifications over the past few years, resulting in SWAT+, a completely revised version of the model (Bieger et al., 2016).

SWAT+ is a complex quasi-physically based water quality model relying on numerous input files and parameters to represent hydrologic, climatic, water quality, management, plant, and soil processes within a watershed, thus this poses a challenge when attempting to set up the model manually (Qi and Grunwald, 2005). Moreover, although snowmelt hydrology is an important subcomponent and prediction of snow accumulation and melting processes are one of the great challenges for SWAT+ (Qi and Grunwald, 2005), but there is a lack of information regarding the validation of SWAT+'s snowmelt season performance (Wang and Melesse, 2005), especially studies of SWAT+ in forested watershed in snowy region are currently lacking.

OBJECTIVE

The objective of this study is to estimate long-term streamflow in forested watershed in snowy region using SWAT+, and to verify the accuracy of the estimation and to confirm the improvement of the accuracy by adjusting parameters. For this, in this study, SWAT+ was used to simulate the daily flow in the Hashigo River in Mishima town, Fukushima Prefecture which is a forested area with a cold and snowy climate. The several parameters were adjusted based on measured data, and the SWAT+ automatic parameter calibration method was conducted to improve the accuracy of model. The calculated river discharge was verified by comparing with the observed.

METHODOLOGY

General Description of Study Site

The study site is the Hashigo River watershed in Mishima Town in Fukushima Prefecture (Fig.1). Hashigo River is a tributary of the Tadami River. The watershed locates at latitude 37.50° - 37.47°, longitude 139.62°-139.63° and range of altitude 350-370 m. Watershed area is 2.85 km², mostly covered by mountainous forest (Table 1). The watershed has 0.4% of paddy field which is located along the main river. Annual mean daily temperature, minimum and maximum daily temperature is 10.6°C, 6.9°C and 15.3°C. The snowfall period is from December to February, and the snowmelt period is from March to April. Rainfall is relatively heavy during the rainy season from June to July, and typhoons are more frequent from September to October. Annual precipitation (2019-2020) was 1,632 mm in 2019 and 1,340 mm in 2020.

Table 1 Land-use of the target watershed

Watershed area (km ²)	Land-use (%)			River length (km)
	Forest	Grass land	Paddy field	
2.85	98.4	1.2	0.4	2.5

Data Analysis Using SWAT+

SWAT creates objects called Hydrologic Response Units (HRUs), which are lumped areas within a subbasin with a combination of land use, soil type, and slope, etc., for simulating all hydrologic

processes occurring in the landscape (Bieger et al., 2016). SWAT+ also introduces Landscape Units (LSUs), which allow for the separation of lowland (wetland) processes from upland processes. The use of LSUs allows for a more detailed classification of HRUs compared to SWAT and increases the number of HRUs. (Kakarndee et al., 2020).

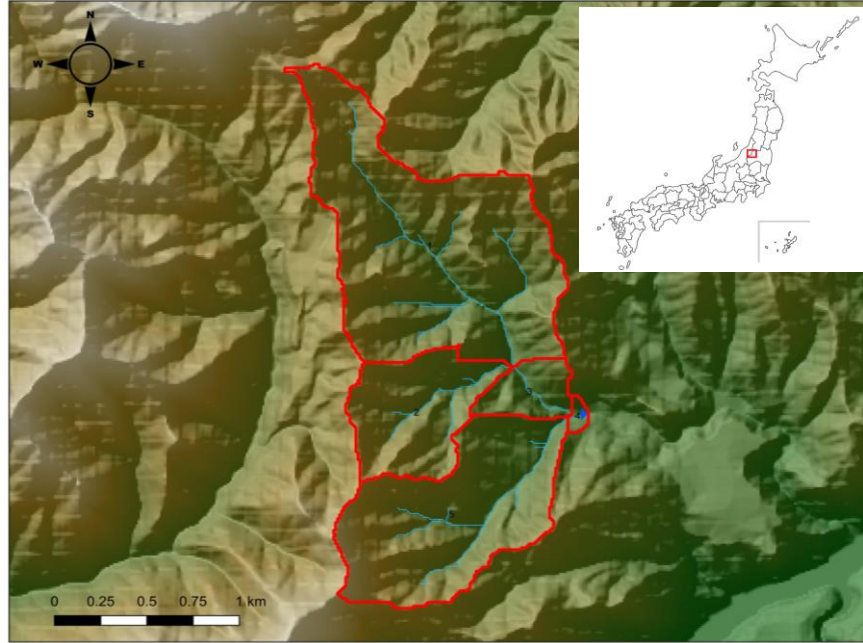


Fig. 1 Location of target watershed (Hashigo River)

The modeling process adopts the water balance method, which is expressed as follows (1).

$$SW_t = SW_0 + \sum_{i=1}^t (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad (1)$$

Where SW_t is the final soil water content (mm), SW_0 is the initial soil water content on day (mm), t is the time (day), R_{day} is the amount of precipitation on day (mm), Q_{surf} is the amount of surface runoff on day (mm), E_a is the amount of evapotranspiration on day (mm), W_{seep} is the amount of water entering the unsaturated zone from the soil profile on day (mm), Q_{gw} is the amount of return flow on day (mm).

The subdivision of the watershed enables the model to reflect differences in evapotranspiration for various crops and soils. Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. This increases accuracy and gives a much better physical description of the water balance (Neitsch et al., 2009). The surface runoff is estimated using the NRCS Curve Number (CN) method (2).

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{R_{day} - I_a - S} \quad \because R_{day} > I_a \quad (2)$$

Where Q_{surf} is the surface runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), I_a is the initial abstraction (surface storage, interception, and infiltration prior to runoff) (mm), S is the retention parameter (mm).

The retention parameter depends on topography (slope), soil, land-use, management practices, and changes with the time due to soil water content (3).

$$S = 25.4 \left(\frac{1000}{CN} - 10 \right) \quad (3)$$

Where CN is the NRCS curve number corresponding to antecedent water content, soil infiltration, land-use and land management conditions (Kakarndee et al., 2020).

Evaluation of the Simulated Data

The Root Mean Squared Error (RMSE) is used to indicate the degree of fit between the simulation and observed values (4).

$$RMSE = \sqrt{\frac{\sum_{i=1}^n EV}{n}} \quad (4)$$

Where EV is error variance (squared of observation value minus simulation value) and n is number of observation days.

The Nash-Sutcliffe Efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance.

$$NSE = 1 - \frac{\sum_{i=1}^n (Q_{obs} - Q_{sim})^2}{\sum_{i=1}^n (Q_{obs} - Q_{ave})^2} \quad (5)$$

Where Q_{sim} is the simulated value (m^3/s), Q_{obs} is the observed value (m^3/s), and Q_{ave} is the average of observed value for the term of simulation (m^3/s).

Q_{sim} and Q_{obs} are respectively the simulated and observed streamflow at time step (m^3/s), P and Q are the corresponding means of the simulated and observed streamflow over the entire period (m^3/s), and n is the total number of streamflow data points.

Description of Spatial Data

The spatial data used in SWAT+ are Digital Elevation Model (DEM), soil and land-use data. 10 meters resolution elevation data obtained from the Geospatial Information Authority of Japan (GSI) was used for DEM. Soil maps were obtained from the National Institute of Agrobiological Sciences (NIAS)'s basic land classification survey data (Shapefile, 1:200,000). The default parameters in SWAT+ database was used for soil parameters. The High-Resolution Land Use and Land Cover Map of Japan (10 m grid size) prepared by the Japan Aerospace Exploration Agency (JAXA) and Earth Observation Research Center (EORC) was used for the land-use data. A 5% threshold area was used to define HRUs applying a 5% threshold means that land-uses, soils and slope ranges whose areas are less than 5% of the subbasin area are eliminated from HRU formation within each subbasin. A total of 123 HRUs were created using these spatial data, 45 of which were defined as actual HURs.

Description of Temporal Data

Daily data for discharge of river (measured at 10-minute intervals) and rainfall, maximum and minimum temperature, relative humidity, solar radiation, and wind speed were measured automatically by networked weather station. The meteorological data are for the years February 2019 to December 2020. In this study, Penman-Monteith was used as the calculation method for evapotranspiration (Okazawa and Takeuchi, 2016).

RESULTS AND DISCUSSION

Simulation of Daily River Discharge

The SWAT+ model was built from the above data. In the first calculation, the default parameters of SWAT database were used for the parameters, and the calculation period was set from February

2019 to December 2020. The calculation results are shown in Fig. 2. The peak river discharge during the rainfall event is higher than Observed value. In addition, the river discharge during snowmelt events (From February to April in 2019 and 2020) is lower than observed data, and the snowmelt rate is not properly reproduced.

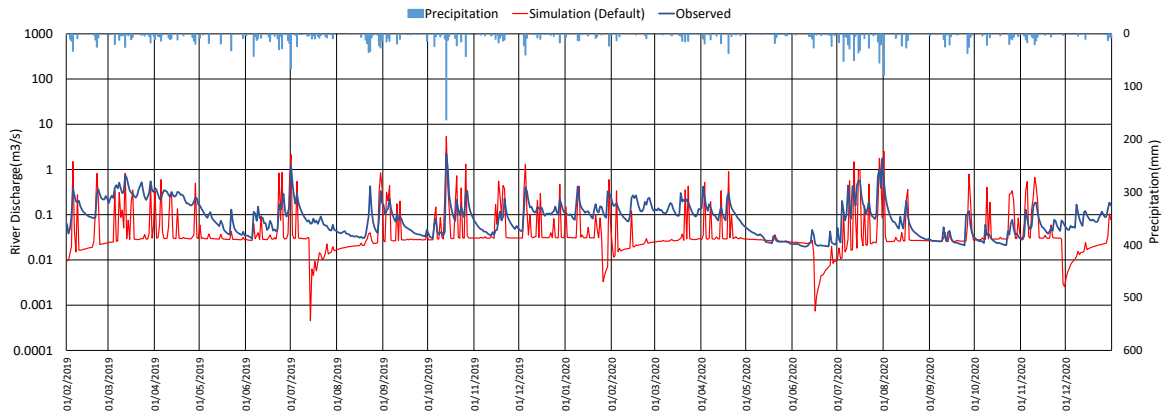


Fig. 2 River discharge of the first simulation results

Simulation after Adjusting Parameters

Comparing the first simulation and observed value, most of the data between December and March was rainfall, and snowfall and snowmelt were not properly reproduced, thus the parameter of snowmelt and snowfall temperature needed to be adjusted. Using the meteorological data which was maximum temperature, average temperature, and snow depth collected at 10-minute intervals by a networked weather station, the snowfall temperature (fall_tmp) and snowmelt (melt_tmp) were calculated to replace the default parameters (fall_tmp: 1.0°C, melt_tmp: 0.5°C). The snowfall temperature was set to the average temperature (2.51°C) on days when there was snowfall (November and March within 2019-2020). The snowmelt temperature was set to the maximum temperature (2.71°C) on days when there was no rain (during December-February 2019-2020) and the snow depth decreased by at least 1 cm.

The peak river discharge of surface runoff in the first simulation was higher than observed data, and it was assumed that parameter of infiltration was not properly recognized in default settings. Therefore, the default parameter which were the saturated hydraulic conductivity of soil layer (soil_k) and the available water capacity of soil layer (awc) were adjusted using the soil data surveyed by the National Institute of Agrobiological Sciences of Japan. The data was input for the first layer (soil_k: 159.84 mm/hr, awc: 0.70 mm/mm) and the second layer (soil_k: 25.20 mm/hr, awc: 0.67 mm/mm).

Simulation After Auto Calibration

In addition to the adjustment of the above parameters, a calibration was conducted using the SWAT+ auto-calibration. The auto-calibration uses the observed value to correct the parameters and improves the value of NSE, RMSE and MSE by repeating the simulation. The auto-calibration can be selected from NSE, RMSE and MSE. In this study, NSE was selected for the auto-calibration. The parameters calibrated for the auto-calibration are those that are difficult to measure and input. In this study, the time of lateral flow travel (lat_time) was calibrated because the time lag between rainfall and groundwater retention time or direct runoff is difficult to measure. The results of adjusting the parameters and the results of automatic calibration of lat_time are shown in Fig. 3.

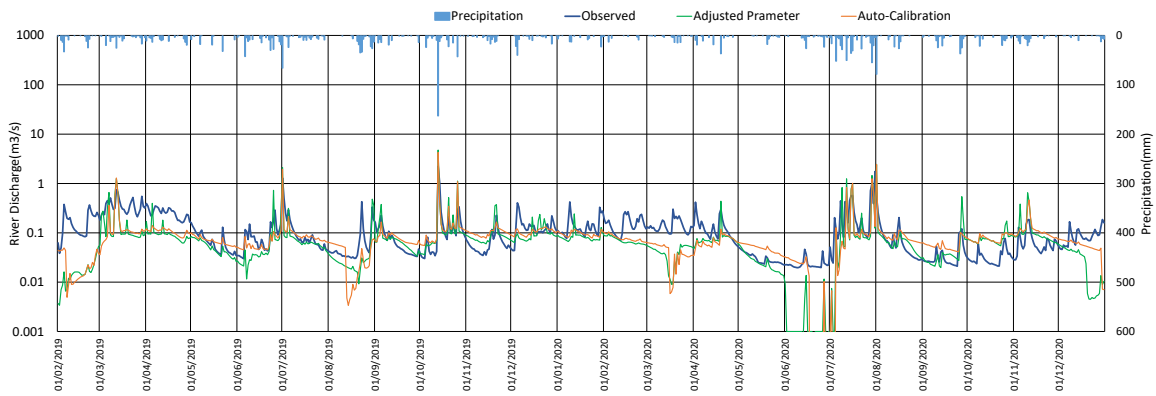


Fig. 3 River discharge of the simulation after calibration of parameters

The river discharge after the calibration within February to April was closer than the first simulation to the observed data. The calibration slowed the decrease in the river discharge after the peak of flow and increased the correlation between simulated and observed values

Accuracy of the Obtained Result

The NSE for each month were calculated from the simulation results of the default parameter, adjusted parameter, and auto-calibration. The results are shown in Fig. 4, where the NSE is an evaluation index that takes into account the variability, and the closer the value is to 1, the highest accuracy. Within Snowfall season (Dec-Feb) and snowmelt season (Mar-Apr), the value of NSE is low, indicating low accuracy. The accuracy of the adjusted parameter and auto-calibration were shown to be improved over the default parameter in NSE. The accuracy is relatively good during the season when there was not much rainfall, while the accuracy tends to decrease from the snowfall season to the snowmelt season (Apr-Dec). The results of calculating the NSE for whole period are -0.70 for default parameter, -0.02 for adjusted parameter, and 0.27 for auto-calibration. The RMSE for each month were calculated from the simulation results of the default parameter, adjusted parameter, and auto-calibration.

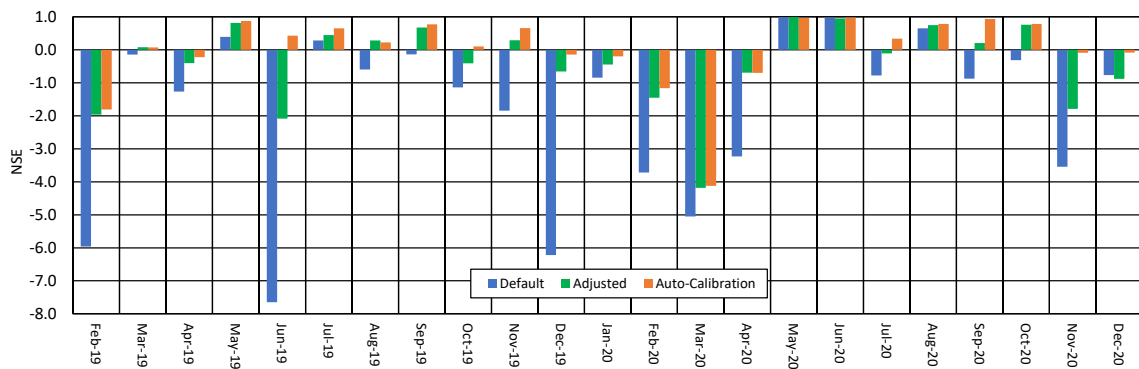


Fig. 4 The monthly NSE of river discharge for each simulation

The results are shown in Fig. 5. The best value of RMSE is 0, which is an evaluation index that emphasizes the difference between the actual value and the observed value. During rainfall events, the value of RMSE is high and the accuracy is evaluated to be low. During low rainfall events, the river discharge is low and the accuracy is better because the difference between observed and predicted values become smaller. The RMSE of auto-calibration has lower values overall and is rated at higher accuracy compared to the other simulations. The RMSE for the whole period was calculated to be 0.21 for the Default parameter, 0.16 for the adjusted parameter, and

0.14 for the auto-calibration.

In the simulation with default parameters, NSE is negative in most months. On the other hand, by adjusting parameters and conducting auto-calibration, some months showed NSE are more than 0.5. RMSE was improved even when auto-calibration was conducted based on NSE. NSE during snowfall and snowmelt (Dec-Mar) is lower than other term, even with parameter adjustments and auto-calibration. It was shown that except for the snowfall and snowmelt season, reproducibility of the river discharge can be secured.

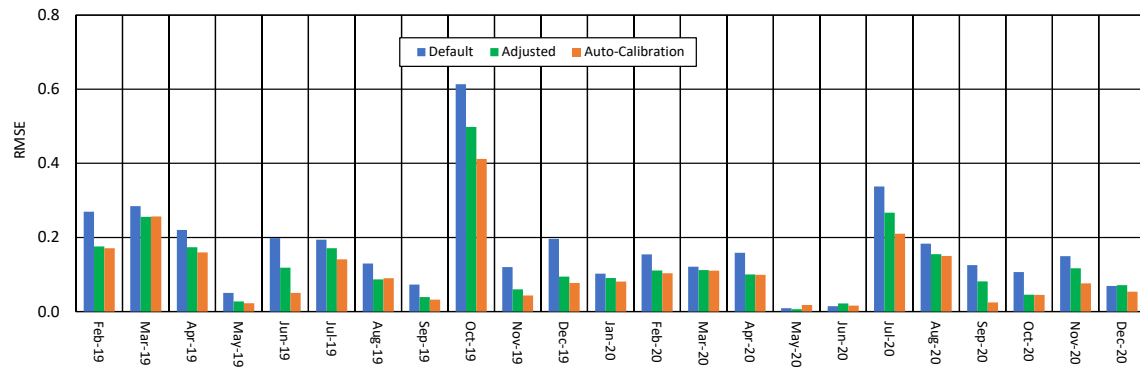


Fig. 5 The monthly RMSE of river discharge for each simulation

CONCLUSION

The accuracy of SWAT+ in forested snowfall areas was verified by simulating river discharge in the Hashigo river in Mishima town, Fukushima prefecture. According to the results, although it was difficult to secure high reproducibility in simulations using default parameters, the accuracy of simulations could be improved by adjusting parameters and conducting auto-calibration. In this study, soil data could not be measured, thus the accuracy of the simulation would be improved by using the actual measured soil data. RMSE was improved even when auto-calibration was performed based on NSE in this study, on the other hand, it is necessary to select the auto-calibration criteria among NSE, RMSE, and MSE according to the purpose because each calibration criteria have different characteristic. It is quite difficult to ensure reproducibility of simulations during the snowfall and snowmelt season compared to other because of the complexity of conditions such as different elevations and slopes, thus to ensure reproducibility of snowfall and snowmelt, setting more detailed conditions are needed for prediction using SWAT+. Although the simulation period was from February 2019 through December 2020, weather and flow data will continue to be measured to verify the accuracy of the simulation.

ACKNOWLEDGEMENTS

This research was supported by the Fukushima Regional Collaborative Research Center (FRECC) in the National Institute of Environmental Studies (NIES) and by Tokyo University of Agriculture as the 2021 Doctoral Research Grant Program of the Research Institute for Agricultural and Life Sciences, and the Strategic Research Project.

REFERENCES

- Bieger, K., Arnold, J.G., Rathjens, H., White, M.J., Bosch, D.D., Allen, P.M., Volk, M. and Srinivasan, R. 2016. Introduction to SWAT+, A completely restructured version of the soil and water assessment tool. *Journal of the American Water Resources Association*, 53 (1), 115-130, Retrieved from DOI <https://doi.org/10.1111/1752-1688.12482>
- Kakarndee, I. and Kositsakulchai, E. 2020. Comparison between SWAT and SWAT+ for simulating streamflow in a paddy-field-dominated basin, Northeast Thailand. *E3S Web of Conferences*, 187, 06002,

- Retrieved from DOI <https://doi.org/10.1051/e3sconf/202018706002>
- Neitsch, S.L., Arnold, J.G. Kiniry, J.R and Williams, J.R. 2009. Soil and water assessment tool theoretical documentation version 2009. Grassland, Soil and Water Research Laboratory, Agricultural Research Service, USA, Retrieved from <https://swat.tamu.edu/media/99192/swat2009-theory.pdf>
- Okazawa, H. and Takeuchi, Y. 2016. Influence of meteorological variable combinations on reference evapotranspiration estimated by the FAO56 Penman-Monteith Method. *International Journal of Environmental and Rural Development*, 7 (2), 147-153, Retrieved from <https://www.iserd.net/wordpress/wp-content/uploads/2017/09/7-2-24.pdf>
- Qi, C. and Grunwald, S. 2005. GIS-based hydrologic modeling in the Sandusky watershed using SWAT. *Transactions of the ASAE*, 48 (1), 169-180, Retrieved from DOI <https://doi.org/10.13031/2013.17960>
- Qin, Y., Abatzoglou, J.T., Siebert, S., Huning, L.S., AghaKouchak, A., Mankin, J.S., Hong, C., Tong, D., Davis, S.J. and Mueller, N.D. 2020. Agricultural risks from changing snowmelt. *Nature Climate Change*, 10 (5), 459-465, Retrieved from DOI <https://doi.org/10.1038/s41558-020-0746-8>
- Wang, X. and Melesse, A.M. 2005. Evaluation of the SWAT model's snowmelt hydrology in a Northwestern Minnesota watershed. *Transactions of the ASAE*, 48 (4), 1359-1376. Retrieved from DOI <https://doi.org/10.13031/2013.19194>
- Williams, J.R., Arnold, J.G., Kiniry, J.R., Gassman, P.W. and Green, C.H. 2008. History of model development at temple, Texas. *Hydrological Sciences Journal*, 53 (5), 948-960, Retrieved from <https://doi.org/10.1623/hysj.53.5.948>



Sustainability of the Implementation of Solid Waste Management: A Comparative Study

MA. MAGDALENA J. BERNALES*

Bohol Island State University, Candijay, Philippines

Email: mamagdalena.bernales@bisu.edu.ph

JAKE C. MALON

Bohol Island State University, Candijay, Philippines

Received 28 February 2022 Accepted 25 July 2022 (*Corresponding Author)

Abstract This study aimed to compare the status of implementation of the Solid Waste Management (SWM) in the Municipality of Candijay, Bohol, Philippines for the year 2015 and 2020 to find ways for the sustainability of the implementation of the Town's Solid Waste Management. Wastes were collected monthly for one year from the five sampled barangays with 122 households. Field investigations, on-site waste measurements and characterizations were conducted. This is a mixed method employing QUANT-Qual approach. Descriptive statistics which include percentages, and weighted mean were used for the quantitative approach while narrative analysis for the qualitative was used. The results revealed that from the previous data of SWM implementation found out that the average biodegradable waste generated in the year 2015 which was 46.14% decreased to 10.94% as a result of home proper waste disposal. Likewise, the recyclable waste which had 27.27%, the number decreased to 26.08%. Since residual wastes should be collected, the collection increased to 59.85% from 15.42% due to acquisition of additional garbage trucks. For special waste, from 11.16% previously collected, it decreased to 3.13%. There was significant difference between the biodegradable, residual and special wastes. In the present SWM implementation, innovation played an important role in recycling waste materials. Shredded plastics and crashed glasses were converted into mixture to create concrete products. The shredded biodegradable wastes were converted into organic fertilizers. The produce out of these shredded materials were used to generate income which played an important role to sustain the solid waste implementation. Thusly, the level of implementation was already properly practiced. Solid Waste Management had employed organizational structure for implementation and dissemination of personnel's function. Additional equipment and personnel were acquired. To sustain the proper SWM, recycling equipment, public awareness, funding, expertise of personnel, equipment and facilities, innovations and other provisions must be provided.

Keywords implementation, innovation, solid waste management, waste characterization

INTRODUCTION

With fast growing population and lack of adequate disposal sites, solid waste has become a major problem for most medium to large-size cities in the Philippines. In recent years, inadequate solid waste management systems have posed serious health risks particularly in densely populated areas.

The increasing problem on waste management in almost all communities across the country was due to the uncontrolled population growth, coupled with rapid urbanization and industrialization, have become the primary thrust of the national government (National Solid Waste Management Commission and D.E.N.R., 2004). In addition, the low level of environmental literacy and awareness of the public, partly contributed to the difficulties in implementing and enforcing environmental laws and policy, particularly, laws on cleanliness and sanitation (Jaworski and DENR as cited by Reyes and Furto, 2013). The common observation is that people are apathetic and indifferent toward wastes issues.

In the Asian region, inadequate solid waste management and disposal practices combined with the tropical climatic condition resulted in an increasing environmental problem (Visvanathan et. al., 2004). In addition, in many rural areas, the lack of environmentally friendly, sustainable and affordable waste management has led to the widespread practice of open dumping and open burning of solid waste (Wilson, 2011). These are the easiest and considered to be the cheapest methods of removing waste from the immediate environment. This predicament made an enormous impact to public health and the environment. While the collection of solid wastes is the responsibility of the local government units (LGUs), these LGUs cannot do it alone. There should be a partnership with other institutions such as the academe, non-government organizations (NGOs), and the community (Machado, 2012). The academe can assist the LGUs through information, education, and communication (IEC) activities. The problem of solid waste and its management has become a genuine concern of the province of Bohol, Central Visayas, Philippines.

In response to the waste problem, the local government of Candijay has adopted measures in the development and implementation of the Ecological Solid Waste Management program. With this, the researchers were triggered to conduct a comparative study to find out the status of implementation of the Solid Waste Management (SWM) in the Municipality of Candijay, Bohol, Philippines for the year 2015 and 2020 and look forward on finding ways for the sustainability of the implementation of the Town's Solid Waste Management.

OBJECTIVE

This study aims to compare the status of implementation of the Solid Waste Management (SWM) in the Municipality of Candijay, Bohol, Philippines for the year 2015 and 2020 to find out the sustainability of Town's Solid Waste Management practices.

METHODOLOGY

The study was carried out in the municipality of Candijay, Bohol, Philippines to determine the average weight of waste generated daily by the household. The data gathered shall be the basis in formulating the 10-year Ecological Solid Waste Management (ESWM) plan of the municipality.

This is a mixed method employing QUANT-Qual approach. Descriptive statistics which include percentages, and weighted mean were used for the quantitative approach while narrative analysis for the qualitative interpretation of information was used. It involved the residents of the selected barangays in the municipality of Candijay as the respondents. Random sampling was used to select the possible barangays to be included in the study. Using Slovin's formula, the researchers used a sample of four (4) barangays with the total number of one hundred twenty-two (122) household respondents and five hundred forty-two (542) household members.

The researchers adopted the questionnaire of Reyes and Furto (2013) and the Questionnaire for solid waste management survey World Health Organization (WHO) 1996 on the level of implementation of proper and improper solid waste management. Minor revisions were made on the questionnaires in order to answer the questioned variable of the study. Since the questionnaire is an adopted one, there is no need to do pilot testing of the said questionnaire. The researcher asked permission to the Municipality's ESWM to disseminate the questionnaire to the selected Barangays. The respondents were also informed about the nature of the study upon the dissemination of the questionnaires.

For analyzing and quantifying the waste generated, respondents were given four (4) plastic bags of different colors like green, blue, yellow and red for biodegradable, recyclable, residual, and special waste respectively. Wastes were collected daily for successive three days and measured according to type. Wastes were segregated in every household before hauling to the dumpsite. Weighing according to type as biodegradable, recyclable, residual and special waste was done in the dumpsite. For qualitative aspects, narrative analysis was also employed, since the study involved interview with the selected informants.

RESULTS AND DISCUSSION

Table 1 exhibits the Comparison on the level of implementation of proper SWM practices of the residents. There were six (6) items which were moderately practiced in the year 2015 that changed to fully practiced in the year 2020. The residents were observed to fully practice the segregation of biodegradable from non-biodegradable, selling of bottles, plastics, cans and other scraps to junkshops reusing of reusable materials, reducing of waste and avoiding the use of toxic and hazardous materials and chemicals. From the four (4) slightly practiced solid waste management in the year 2015, it can be seen that these practices were already fully practiced except for recycling which was moderately practiced. The study of (Atienza, 2013) pointed out that the lack of infrastructure for efficient transportation contributed in the inefficient implementation and ineffective monitoring of waste management program which was already addressed by the municipal solid waste management with the cooperation of the people in the community.

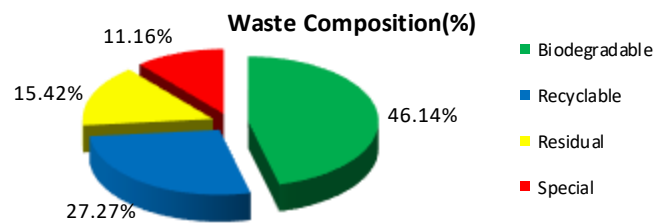


Fig. 1-A Composition of waste generated during 2015

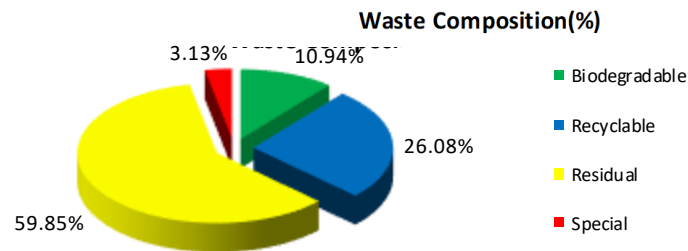


Fig. 1-B Composition of waste generated during 2020

Table 1 Level of implementation of proper solid waste management practices (N=122)

Items	Weighted Mean		Descriptive Value	
	2015	2020	2015	2020
1. Segregating of biodegradable from non-biodegradable wastes	3.01	3.6	MP	FP
2. Collecting of garbage by the municipal truck	2.41	3.5	SP	FP
3. Selling of bottles, plastics, cans and other scraps to junkshops	3.01	3.5	MP	FP
4. Reusing of reusable materials	2.51	3.7	MP	FP
5. Reducing of waste	2.50	3.6	MP	FP
6. Recycling	2.40	3.8	SP	MP
7. Feeding left over foods to pets	3.60	3.9	FP	FP
8. Avoiding the use of toxic and hazardous materials or chemicals	2.81	3.6	MP	FP
9. Composting	2.42	3.7	SP	FP
10. Providing of garbage receptacles to public areas	2.39	3.9	SP	FP
Composite mean	2.70	3.68	MP	FP

Range: 1.0-1.49: not practiced (NP), 1.5-2.49: slightly practiced (SP), 2.5-3.49: moderately practiced (MP), 3.5- 4.0: fully practiced (FP)

Table 2 Improper solid waste management practices (N=122)

Items	Weighted mean		Descriptive value		Rank
	2015	2020	2015	2020	
1. Burning of garbage in every household	3.01	2.1	MP	SP	1
2. Dumping garbage in rivers.	1.30	1.1	NP	NP	4
3. Paying somebody to throw garbage anywhere far from their residence	1.35	1.15	NP	NP	3
4. Burying of hazardous waste underground	2.03	1.5	SP	NP	2
Composite mean	1.92	1.46	SP	NP	

Range: 1.0-1.49: not practiced (NP), 1.5-2.49: slightly practiced (SP), 2.5-3.49: moderately practiced (MP), 3.5- 4.0: fully practiced (FP)

Table 2 presents the transition of the level of implementation of improper solid waste management. In the year 2015, burning of garbage in every household was moderately practiced, however, as compared to the year 2020 this kind of act was change to slightly practice. Burying of hazardous wastes underground was slightly practiced in the year 2015 and in the latest data in the year 2020, this was not anymore practiced. It was worth to note that dumping of garbage in rivers and paying somebody to throw garbage anywhere far from their residence were remained not practiced. The household respondents were already concerned with the effects of the emitted smoke on the atmosphere and to the health of the people. With the effort of the town's solid waste management office through information dissemination, the residents were not anymore practicing the burying of hazardous wastes underground. According to (Reyes and Furto, 2013) though these materials are buried, there are still harmful effects to the people's health but not as much as those which are exposed above the ground.

Table 3 Problems encountered in the implementation of solid waste management (N=122)

Items	Weighted mean	Descriptive value	Rank
1. Increasing population	2.55	S	6
2. Public Indifference (Public don't care)	2.56	S	5
3. Inefficient collection of garbage	2.04	S	10
4. Lack of financial resources	3.5	VS	3.5
5. Lack of authority to make financial decision	2.3	NS	10
6. Non-operation of good disposal	2.4	NS	9
7. Lack of trained personnel	3.5	VS	3.5
8. Lack of enforcement measure and capability	3.6	VS	2
9. Foul odor of the open dumpsites that is hazardous to health	3.7	VS	1
9. Lack of awareness among the people regarding SWM	2.44	NS	8
10. Lack of training on proper solid waste management practices	2.48	NS	7
Composite mean	3.10	S	

Range: 1.0-1.49: not a problem (NP), 1.5-2.49: not so serious (NS), 2.5-3.49: serious (S), 3.5-4.0: very serious (VS)

Table 3 shows that item number 9 "Foul odor of the open dumpsites which were hazardous to health" got the highest rank with a weighted mean of 3.7 with descriptive value of very serious. The next in rank is the lack of enforcement measure and capability had a weighted mean of 3.6 with a descriptive rating of very serious. The lowest was on the item number 5 "lack of authority to make financial decision" with a weighed mean of 2.3, not serious. The overall perception of the respondents in terms of the problems encountered is serious with a weighted mean of 3.10. It implies that lack of enforcement measure and capability, trained personnel and financial resources are encountered very seriously by the respondents. Problems such as increasing population, public indifference were encountered in a serious manner while lack of training on proper solid waste management practices is encountered not seriously. The result of the study is supported by the study of (Ali et. al., 2013) entitled open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city wherein the main environmental problem associated with the disposal site is the potential risk to the soil.

Table 4 Difference of waste generation by weight in terms of grams and level of implementation of solid waste management practices

Items	F _{computed}	F _{table}	Interpretation
Proper and Improper Solid waste Management Practices	-29.79	7.815	Significant
Waste Generation	10.14	7.815	Significant

Table 4 presents the difference on the level of implementation of solid waste management practices among the different barangays in the municipality of Candijay. It can be gleaned from the table that the computed F values of proper and improper solid waste management practices and waste generation were -29.79 and 10.14 respectively which is beyond and greater than the tabular value of 7.815 at 0.05 level of significance. Thus, the null hypothesis of no significant difference is rejected. This means that there is a difference that exists on the level of implementation of solid waste management. Differences were indicated from the result using Kruskal Wallis test. There was a difference that exists on the level of implementation of solid waste generated among the different barangay. This could be due to the factors such as location, population, facilities and possibly to the income of the community. Densely populated barangays like Poblacion and Cogtong generate more solid waste making their SWM practices different from those scarcely populated as in Tugas and San Isidro. It is where the difference lies in terms of weight of waste generated. Moreover, Cogtong is a coastal barangay where in the respondents may throw their waste in the seas aside from burning. In addition to that there is a part of Poblacion that is adjacent to the river where waste can be found.

Improvement Highlights

The average biodegradable waste generated in the year 2015 which was 46.14% decreased to 10.94% in the year 2020 as a result of home proper waste disposal. Likewise, the recyclable waste which had 27.27%, the number decreased to 26.08%. Since residual wastes should be collected, the 2020 collection increased to 59.85% from 15.42% in the year 2015, this is because of the acquisition of additional garbage trucks. For special waste, from 11.16% previously collected, it decreased to 3.13% in the year 2020. For this, it can be deduced that there was significant difference between the biodegradable, residual and special wastes. In the present SWM implementation, innovation played an important role in recycling waste materials. Based on the 2015 data, there were problems identified in the implementation on the management of the solid waste in the town of Candijay. These identified problems were considered as the immediate concern which needed to be eradicated. In 2020, through observation in the locale and interview of the selected individuals, it was found out that in the present SWM implementation, innovation played an important role in recycling waste materials. Acquisition of shredder for biodegradable, plastics and glass waste materials were already realized. Shredded plastics and crashed glasses were converted into mixture to create concrete products like bricks and hallow blocks. On the other hand, the shredded biodegradable wastes were converted into organic fertilizers. The produce out of these shredded materials were used to generate income which played an important role to sustain the solid waste implementation. Thusly, the level of implementation was already properly practiced. Solid Waste Management had employed organizational structure for implementation and dissemination of personnel's function. Additional equipment and personnel were acquired. To sustain the proper SWM, recycling equipment, public awareness, funding, expertise of personnel, equipment and facilities, innovations and other provisions were already provided

CONCLUSION

Based on the findings of the study, the following conclusions are drawn: a) the most produced waste in the 2015 was the biodegradable which was tremendously reduced in the 2020 data b) the level of implementation on proper solid waste management by the residents was already fully

practiced while Improper Solid Waste Management was never practiced yet there were still few household who slightly practiced the burning of waste c) because of the identified problems encountered in the implementation of solid waste management in the year 2020, the concerned agency addressed these problem through the following; close monitoring of the open dumpsite which caused unpleasant odors, provide enforcement measure and capabilities, acquiring of well trained personnel and financial resources, efficient collection of garbage to a maximum level d) different barangays in the municipality of Candijay had unified scheme in responding the implementation of solid waste management e) mandate households to do recycling of the recyclable waste materials, f) with the effectiveness of the SWM implementation and serious reinforcement of the concerned agency, it's level of implementation of solid waste management practices was fully practiced and dramatically improved which turned out as the key for implementation sustainability.

ACKNOWLEDGEMENTS

The authors acknowledge the following; Municipal Mayor of Candijay, Bohol, Philippines through Municipal Planning and Development Office (MPDO), The Office of the Sangguniang Bayan (Municipal Council), Municipality of Candijay, Province of Bohol for providing the documents needed in the study, Municipal Ecological Solid Wastes Management and MENRO office.

REFERENCES

- Ali, S.M., Pervaiz, A., Afzal, B. Hamid, N. and Yasmin, A. 2014. Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city. *Journal of King Saud University - Science*, 26 (1), 59-65, Retrieved from DOI <https://doi.org/10.1016/j.jksus.2013.08.003>
- Atienza, V. 2013. Review of the management system in the Philippines, Initiatives to promote waste segregation and recycling through good governance. Kojima and Michida (Eds.), *Economic Integration and Recycling in Asia, An Interim Report*, Chosakenkyu Hokokusho, Institute Developing Economics, 65-97, Retrieved from <https://www.nswai.org/docs/Review%20of%20the%20Waste%20Management%20System%20in%20the%20Philippines.pdf>
- Bahadir, A. 2013. The importance of energy and the use of energy as a power of factor. *Journal of Energy Technologies and Policy, Special issue for International Conference on Energy, Environment and Sustainable Economy*, 3 (11), 6-15, Retrieved from <https://www.iiste.org/vol-3-no-11-2013-journal-of-energy-technologies-and-policy/>
- Chiemchaisri, C., Juanga, J.P. and Visvanathan, C. 2004. Municipal solid waste management in Thailand and disposal emission inventory. *Environmental Monitoring and Assessment*, 135, 13-20, Retrieved from DOI <https://doi.org/10.1007/s10661-007-9707-1>
- Machado, T.M. 2012. Challenge on municipal solid waste management in Cagayan de Oro city, mulberry suites, Cagayan de Oro city. Retrieved From https://pcieerd.dost.gov.ph/images/downloads/presentation_materials/gmi_06272012/07_SWM_of_CDO_Machado.pdf
- Reyes, P.B. and Furto, M.V. 2013. Greening of the solid waste management in Batangas city. *Journal of Energy Technologies and Policy, Special issue for International Conference on Energy, Environment and Sustainable Economy*, 3 (11), 187-194, Retrieved from <https://research.lpubatangas.edu.ph/wp-content/uploads/2014/04/JETP-Greening-of-the-Solid-Waste-Management.pdf>
- Wilson, D.C. 2011. Acting alone to partnerships, Strategic approach for sustainable municipal waste management. UN-Commission for Sustainable Development (CSD), *International Conference on Building Partnerships for Moving toward Zero Waste*, Retrieved from <https://www.uncrd.or.jp/>
- World Health Organization (WHO). 1996. Questionnaire for Solid Waste Management Survey. Retrieved from https://www.academia.edu/28925080/Questionnaire_for_Solid_Waste_Management_Survey



Disparity in Quality of Life and Education Attainment of Children within the Tea Sector: Case Study in Low-Country in Sri Lanka

YUKO FUKUDA*

*Organization for the Strategic Coordination of Research and Intellectual Properties,
Meiji University, Ikuta, Japan
E-mail: yukotsu70@yahoo.co.jp*

EIJI YAMAJI

Graduate School of Frontier Science, The University of Tokyo, Kashiwa, Japan

Received 2 February 2022 Accepted 25 July 2022 (*Corresponding Author)

Abstract In Sri Lanka, household income and living standards in the estate sector are lower than those in other sectors. The tea sector is an important industry in the estate sector, where the structure has changed over time, with an increase in smallholders and improvements in living conditions. This change has made the living environment and educational opportunities within the tea sector no longer uniform. This paper aims to identify the disparity in quality of life and education attainment of children and attempts to describe the structure of the differences behind these disparities by focusing on the three management types. Quantitative and qualitative methods were applied to this analysis. Primary data for 302 households were collected between 2013 and 2015. Six indicators of the environment surrounding children and two indices of education attainment were used. Four indicators show statistically significant disparities among management types. A comparison between the six indicators and management types indicates that people on the PEs are more likely to live under the low quality of life and face the difficulties, which are related to the social structure of the management type to which the households belong.

Keywords children, disparity, quality of life, education, tea sector

INTRODUCTION

This study focuses on the environment surrounding children and the education attainment of children between management types in the tea sector. Sri Lanka has been a transit point for trade for centuries, and was colonized by Western countries in the early 16th century. Tea was developed as a colonial plantation crop by the British Empire. After independence in the 1970s, large-scale estates were nationalized, and later, their management was privatized. Concurrently, private estates could expand the cultivation area, and smallholders have been encouraged to join the tea cultivation, so that the management types of tea cultivation have been no longer uniform. The transition to a market-based economy in 1990s and the end of the civil war in 2009 led to social development and diversification of people's values, which also have expanded the employment opportunities outside the estates. Today, people need to have more than a basic education to work and live outside the estates.

Many studies have reported on the living environment and education attainment of children living on estates as well as on the recent improvements in estates, while there have been few comparative studies focusing on the management type. This study attempts to delineate the differences in quality of life and education attainment of children based on management type. The context and structure behind these differences have also been described.

MATERIALS AND METHODS

A descriptive design was applied to this analysis. The results presented in this paper are based on the quantitative and qualitative methods of primary data collection. Questionnaires and interviews were collected between 2013 and 2015 in Kotapola Division, located in the northern part of the Matara district, where the tea sector is economically important. Tea cultivation in this area is carried out by Regional Plantation Company-RPC, Private Estate-PE, and Individual Farmer-IF.¹ The sample size is 302 housing units, comprising 103 households in 2 RPCs, 100 on 19 PEs, and in 99 IFs in a total of 11 villages. Table 1 shows an overview of children aged 5-17, target children are 196 in RPCs, 205 on PEs, and 133 in IFs.

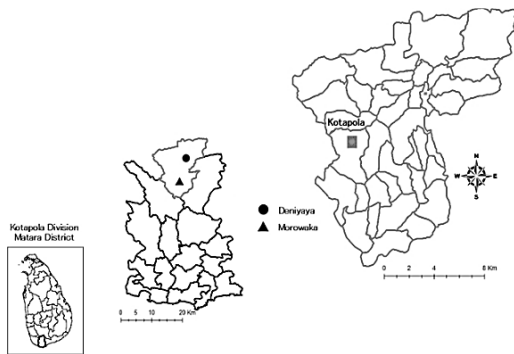


Table 1 Number of households, people and children

	RPC	PE	IFs
Household:	103	100	99
People:	491	480	424
Children:	106 (Boy) 90 (Girl)	117 (Boy) 88 (Girl)	72 (Boy) 61 (Girl)

Fig. 1 Location of Morowaka and Deniyaya

The questionnaire is based on the Child Activity Survey 2008/09 (CAS 08/09),² which was jointly conducted by the Sri Lankan government and the International Labour Organization (ILO). This study used the same variables as in the CAS 08/09. The quantitative analysis used the environment and education attainment as the dependent variables and the management type as the independent variable, and conducted a χ -square test³ to find the differences in the environment and education attainment among management types. The environment surrounding children consists of six indicators: a. household income, b. head of household education level, c. housing condition, d. environmental safety, e. economic activities and f. housework activities of children. The education attainment consists of two indices: attendance and repeated years/dropouts.

FINDINGS

1. Environment Surrounding Children

Quality of life is an important aspect of individual well-being. Indicators a and b focus on the household condition, selecting the economic status of the household and the educational achievement of the head of the household. Indicators c and d focus on living conditions, selecting the variables of privacy and settlement status, and safe and sanitary environment. Indicators e and f both focus on the activity status of children at home, selecting economic activities to earn income and housework activities for family.

¹ The RPCs were composed of 12-29 estates and managed 15,000-25,000ac of cultivated land, but they had not enough assets, which prevented funding for new investments, causing difficulties in management (Nihal 2011). In order to improve the RPCs' management, privatization was carried out in 1995 through the sale of 51% of the controlling interest in each, initially 20 RPCs were privatized and later 3 RPCs were added (ADB 2004). Their tea land is currently leased from the government for 99 years, and 286 plantations are managed by 23 RPCs (MPI 2012). Between 1951 and 2005, the number of small farmers increased by 368%, while estates with 100ac or more declined by 57% (Herath and Weersink 2007). The present management type is State-owned estates, RPC, PE, and IF.

² The CAS data covers the demographic characteristics of children, their school attendance, economic activities, health and safety, housing, and household characteristics. It also presents information on perception of parents/guardians on their children working and other characteristics pertaining to the children aged 5-17 years. Data in this paper extracted 3,683 households from 9 districts where mainly tea estates were located.

³ In this paper, p-value less than 0.05 is considered statistically significant.

Household conditions: The impact of family situation on children has been studied in various fields. Table 2 shows the household income by management type. The average monthly income of 302 households is Rs. 26,970, while it is Rs. 25,151 in the RPCs, Rs. 26,534 on the PEs, and Rs. 29,303 in the IFs. Though IFs have a higher average income, more IF households are below the poverty line.⁴ This is because of the different income structures of each management type. The main source of income for IFs comes from the sale of tea leaves and side jobs, whereas for estate households, it is the salary from the estate.

Table 2 Household income

	RPC	PE	IFs
Average Income	Rs. 25,151	Rs. 26,970 Rs. 26,534	Rs. 29,303
Poverty Line		5,511 Rs	
No of Household below Poverty Line	9	6	16
Household Income	<20K: 58 (29.6%) 20K<30K: 73 (37.2%) >30K: 65 (33.2%)	56 (27.3%) 72 (35.1%) 77 (37.6%)	45 (33.8%) 38 (28.6%) 50 (37.6%)

Rs.130 =1USD in 2014

Table 3 Head of household education level

	RPC	PE	IFs
None	57 (29.1%)	102 (49.8%)	6 (4.5%)
Low*	111 (56.6%)	89 (43.4%)	63 (47.4%)
High**	28 (14.3%)	14 (6.8%)	64 (48.1%)

* Low: Grade 9 (compulsory education) or less

** High: above compulsory education

IFs' income comes from harvest yield, which is highly dependent on the cultivation area, as well as from other crops or jobs. The greater the cultivation area or more side jobs they have, the higher the income they receive. At the time of the survey, tea leaf disease was prevalent, reducing tea leaf yield and their income. Though social security is available, they generally do not receive it because they do not enroll in it. The main source of income for people on estates comes from the estate itself. The salary for RPC employees is uniform whereas for PE employees, it varies from estate to estate. For RPCs, the salary is decided every other year through wage board discussions held by RPCs and trade unions and government. This was Rs. 620 (Rs. 450 + benefits) per day in 2014.⁵ The salary is not reduced if employees appear, even if they do not meet quotas. They also receive Employees Provident Fund (EPF), Employment Trust Fund (ETF)⁶, gratuity, attendance bonus, profit bonus, and other benefits. For PEs, the daily salary is generally lower than that of RPCs in the range of Rs. 350-500.⁷ Salary is not paid if an employee is unable to work for any reason. Benefits, such as EPF and ETF, are guaranteed on larger estates, but are not always guaranteed on the medium-sized and not guaranteed on the small estates.

The cross-sectional analysis of household income among children shows that it is not statistically significant between management types, but it is statistically significant for the head of household education level. This indicates that there is no large difference in household income among children by management type (Table 2), but there is a difference in the head of household education level between IFs and the two estate types (Table 3). The difference in the head of household education level may be attributed to the social conditions of the time in which they were born. Their average age was 52 years old, indicating that they were born in the 1960s and the 1970s. The nation was growing economically, but due to regional disparities and internal conflicts, compulsory education could not be implemented nationwide and equal educational opportunities were not available.⁸

Living conditions: The living space in which children live has a significant impact on their development. In many countries, owning a home is a status symbol, but it also protects privacy and keeps people from moving from place to place. It also helps to create an environment in which

⁴ Poverty Line: taken as half the median household income of the total population

⁵ According to Manager, if employees were registered as full-time workers, 25 working days per month were guaranteed with 17 days paid holidays per year, with nominal quota of 20-22kg of leaf plucked per day. Salary is guaranteed regardless of weather or insufficient yield.

⁶ EPF is a social security scheme of employees and EPF is to help employees to save a fraction of salary every month.

⁷ Work schedule was around 22 days per month and quantity of leaf plucking was determined to be around 25kg per day,

⁸ This survey also found that the higher their education level, the more they perceived education as important and vice versa.

children can settle down. Living conditions were divided into two indicators. One focuses on the housing itself, whereas the other focuses on the environmental safety of the living space. Housing condition is generated from three variables: i. ownership (not owning single house=0, and owning a single house=1), ii. type of housing (line house=0, single house=1); and iii. the number of rooms for each person (less than one room=0, more than one room=1). It is classified as high if all three are satisfied, medium-high if two are satisfied, medium-low if one is satisfied, and low if none are satisfied. Environmental safety is generated from four variables: i. safe drinking water (unsafe=0, safe=1), ii. exclusive toilet facilities (shared or none=0, owned=1), iii. safe lighting source (no lighting or non-electricity=0, electricity=1); and iv. safe energy sources for cooking (non-gas/electricity=0, gas/electricity=1). It is classified as high if all four are satisfied, medium-high if three are satisfied, medium if two are satisfied, medium-low if one is satisfied, and low if none are satisfied. Table 4 shows the housing condition and environmental safety of children by management type.

The cross-sectional analysis of housing condition and environmental safety among children between management types is statistically significant. Table 4 shows that housing condition is different between management types and that children on PEs are more likely to live in lower housing condition. This is because IFs own a single house, whereas most children living on the estates live in the provided line-house, which has 1-2 rooms⁹ or a single room with a veranda. Thus, most of the IFs' children belong to the medium category or above, but most of the children of the two estate types belong to the low category. Line-houses originally were built for temporary workers during the coffee plantation era, when the plantation economy was introduced, and estate owners have provided them to workers who do not have access to housing. Line-houses have remained in the traditional manner and are often regarded negatively, as a relic of the colonial period. A notable difference between RPCs and PEs is their right to residency. People in RPCs can stay in line-houses after retirement, even if their family members are not working,¹⁰ but people on PEs cannot stay unless they are working, and are required to move out after leaving their jobs.

Table 4 Housing condition and environmental safety

Housing	RPCs	PEs	IFs	Safety	RPCs	PEs	IFs
Low	140 (74.5%)	140 (71.8%)	N/A	Low	3 (1.5%)	N/A	1 (0.8%)
Medium-low	41 (21.8%)	19 (9.7%)	N/A	Medium-low	13 (6.7%)	28 (13.7%)	2 (1.5%)
Medium-high	7 (3.7%)	28 (14.4%)	104 (78.2%)	Medium	120 (61.5%)	135 (66.2%)	81 (61.0%)
High	N/A	8 (4.1%)	29 (21.8%)	Medium-High	58 (29.8%)	41 (20.1%)	49 (36.7%)
				High	1 (0.5%)	N/A	N/A

Low=0, Medium-low=1, Medium-high=3, High=4

Low=0, Medium-low=1, Medium=3, Medium-high=4, High=5

Environmental safety in the survey villages was recognized as the second from the bottom of 650 divisions in Matara (DCS 2013) and the CAS 08/09 indicated that it on estates was worse than on non-estates. This survey observes a similar distribution between the estates and IFs; when comparing RPCs with PEs, PEs are in a lower category. Overall, this survey found that children living on PEs tend to live under more unstable and less secure living conditions than IFs and RPCs.

Children's activities: Doing some work for the family is a social and cultural norm in Sri Lanka. Long hours of these activities not only take children away from school, but also deprive them of the opportunities they need to experience as children, which adversely affects their health and development. This study categorizes children's activities into two indicators: one focusing on economic activities and the other on housework activities for the family. Our survey found that the average number of hours spent by children on daily activities (sleeping, eating, leisure, school, and housework) was around 20.5 hours, suggesting that economic activities¹¹ that exceed 3.5 hours may affect other activities. Table 5 shows the definition of child labour used in this study and Table 6 shows the average activities' hours and activities status.

⁹ Space of a room is approximately 10 feet×12 feet. People owning a house was 15% in RPC and 28% on PEs.

¹⁰ Ownership belongs to the RPCs.

¹¹ Economic activities are mainly engagement in tea cultivation or working for the family business, regardless of having income or not.

Table 5 Definition of child labour

Age	Economic Activities	Housework Activities
5-12 years	More than 5 hours a week	More than 15 hours a week
12 year and over	More than 15 hours a week	More than 25 hours a week

Table 6 Children’s activities

Economic Activities	RPCs	PEs	IFs	Housework Activities	RPCs	PEs	IFs
Average hours	1 hour and 14 min			Average hours	1 hour and 20 min		
None	173 (95.6%)	169 (87.6%)	99 (76.2%)	None	46 (25.4%)	48 (24.8%)	34 (26.2%)
Work	008 (4.4%)	12 (6.2%)	25 (19.2%)	Housework	108 (59.7%)	109 (56.5%)	74 (56.9%)
Child labour	—	12 (6.2%)	6 (4.6%)	Child labour	27 (14.9%)	36 (18.7%)	22 (16.9%)

The cross-sectional analysis of children’s economic activities is statistically significant between management types, but that of housework activities is not statistically significant. This indicates that differences among children exist in economic activities, but not in housework between management types. The average daily activity time of the children engaged in economic activities was 1 hour and 14 minutes. Children in RPCs were not engaged in child labor, whereas 6.2% of children on PEs and 4.0% of those in IFs were engaged. As for housework, many children in all management types worked for their families, with average daily activity time of 1 hour and 20 minutes. Child labor engagement is 14.9% for RPC, 18.7% for PEs and 16.9% for IFs. Children on PEs are more likely to engage in child labour.

2. Education Attainment and Educational Environment

This survey found that 86.1% of households stated the importance of education for their children, and wished for them to have a better future through high-quality education and professional knowledge. Figure.2 represents the children's school attendance by management type, and Figure.3 represents the repeated years/drop-out experiences. In terms of management types, the cross-sectional analysis of both education attainment is statistically significant.

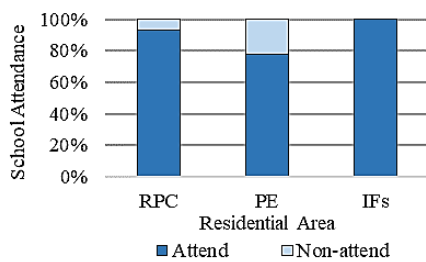


Fig. 2 School attendance

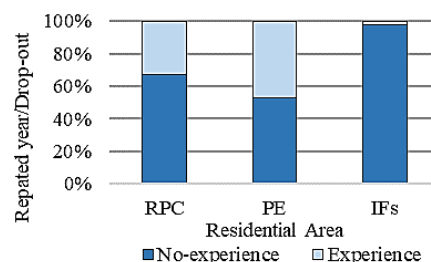


Fig. 3 Repeated years / dropout

All IFs children attended, whereas 6.9% and 22.4% in RPCs and PEs did not attend, indicating that attendance of children living on the PEs was poor (Fig.2). For repeated years/dropout experiences, the same trend can be observed; 33.2% in RPCs and 47.4% on PEs were not in the appropriate grade for their age (Fig.3).¹²

The cost of education can be noted as a factor in giving up children's education. This includes stationery, reference books, transportation, private tutoring fees, and school repairs. Transportation to and from school increases the burden of educational expenses, and has a bearing on commute

¹² Secondary analysis of the CAS 08/09 data showed that the ratio of school non-attendance was around 10.3% in the non-estate sectors, while around 15.5% on estates.

safety (Wal, 2008).¹³ The average expenditure per child is Rs.1,324 overall; Rs.960 for RPCs, Rs.855 for PEs, and Rs.2,583 is for IFs. The percentage of households not spending is 2.6% for RPCs, 14.6% for PEs, and 1.5% for IFs, indicating that IFs spend more on their children's education than RPCs and PEs.

Behind this education expenditure is the attribution that each management type has. Children in IFs could go to relatively large schools, better equipped, and with better-quality teachers located in the central town, but it requires for school facilities and the distance from their home requires more time and money to commute. Children in RPCs go to schools on estates or locally, and school buses are arranged for those whose residential areas are far from schools. Children on PEs usually go to schools close to their home so that they do not require long-distance walking or transportation (Table 7). However, if children wish continue with senior secondary education (≥ 12 grades), there is likely to be no school on the estate or near home.¹⁴ Thus, they must take a bus for commuting, which costs the household.

This survey found that the educational environment of both estates' households is more favorable in terms of distance, time, and modes than IFs, but less favorable in terms of quality of education and educational opportunity.

Table 7 Distance from home to school and mode of travel

	RPC	PE	IFs		RPC	PE	IFs
<1km	58 (34.5%)	44 (28.2%)	13 (10.2%)	Walking	87 (50.6%)	89 (56.7%)	23 (18.0%)
1 \leq 3km	48 (28.6%)	82 (52.6%)	25 (19.7%)	Car/ Motorbicycle	16 (9.3%)	2 (1.3%)	13 (10.2%)
3 \leq 5km	43 (25.6%)	23 (14.7%)	14 (11.0%)	Bus/School bus	69 (40.1%)	66 (42.0%)	92 (71.8%)
>5km	19 (11.3%)	7 (4.5%)	75 (59.1%)				

DISCUSSION

This study attempts to delineate the disparity in quality of life and educational environment and examine how these are related to the social structure of the management type to which the households belong.

Table 8 Quality of life and education attainment between management types

<u>Household Condition</u>		<u>Living Condition</u>		<u>Children Activity</u>		Education Attainment
H-income	Head Ed	Housing	Safety	Economic	Housework	
No different	Different	Different	Different	Different	No different	Different

χ -square test ($p=0.05$): Significant = Different, No significant = No different

Table 8 shows the result of χ -square test on the quality of life and education attainment of children. This survey found that four indicators show statistically significant disparities among management types. The results of the comparison between the six indicators and management types indicate that people on the PEs are more likely to live under the low quality of life and face the difficulties, which are related to the social structure of PEs.

Table 9 presents an overview of the social structure of each type of management. IFs are self-employed and their income depends on the amount of tea leaves harvested and their side jobs. While both estate types' workers are salaried, employment conditions for RPCs are more secure

¹³ Tea cultivation areas are generally located on the slope in the mountain. In the survey area, buses are available on the main roads, but not on the side roads or narrow streets, in which covered with trees and grass, and few road lamps and few pedestrians. Therefore, family who arranges a travel mode such as bike, car or three-wheeler drives their children to school for safety.

¹⁴ Schools below university are in Sinhala or Tamil medium. Most the children living on the estate go to Tamil medium schools, but are limited. Only one school of Grades 12 and above is available. (5 schools in Tamil medium in Matara, 4 schools are located in the survey areas)

than for PEs. Low-income households are unable to make ends meet, which is a factor in child labor and leads to non-spending on child education. As shown in Table 2 and Figure 2 and 3, despite the fact that a larger number of low-income IF households are below the poverty line, their children's education attainment is better than that of either estate type. This indicates that children's education attainment is not only related to household income, but also to a combination of factors such as the stability of one's livelihood, living environments, the educational environment, and parental awareness.

Table 9 Social structure of each management type of tea sector

	Estates		IFs
	RP	PE	
Cultivation area	≥ 50 ac	Large (L) ≥ 50 ac Medium (M) 50–10ac Small (S) ≤ 10 ac	around 0.5–5ac
Living Zone	Estate	Village & Town	Village & Town
Household Condition	<ul style="list-style-type: none"> •Salary: Same for all RPCs decided based on negotiation with RPC & Trade Union •EPF, ETF, Other benefits 	<ul style="list-style-type: none"> •Salary: Depend on the estate •L : EPF, ETF, Other benefits M: depend on estate S : generally, no-benefits 	<ul style="list-style-type: none"> •Productivity & Side business • Generally not join in Social security
Living Condition	<ul style="list-style-type: none"> •Residence: Generally provided by the estate, long-term workers have residency rights after retirement. • Managed by PRCs, but residents can modify. 	<ul style="list-style-type: none"> •Residence: Generally provided by estate, but residency rights depend on the estate. •Managed by PE. Residents can modify if owner allows. 	<ul style="list-style-type: none"> •Owing land & house •Maintain by themselves
Education	<ul style="list-style-type: none"> •Pre-school: provided by estate •1-11G: on estate or nearby home •12-13G: Generally outside Town 	<ul style="list-style-type: none"> •Pre-school: in village •1-11G: generally nearby home •12-13G: Generally outside Town 	<ul style="list-style-type: none"> •Pre-school: in village •1-13G:nearby home/town/city

This survey found that estate workers and families usually live in residences provided by the estate where they work, and their children go to schools nearby or on the estate. However, while the right of residence is recognized in RPCs, it is often not granted on PEs. PE workers who quit their jobs often move with their families to new estates that offer better salaries and benefits. It seems that they have more freedom of choice in their living conditions than those living in RPCs or IFs do. If the new residence is in the same living area, children can commute to the same school as before, but the change in commuting condition may exacerbate their financial burden. Moreover, relocation between estates can affect the stability of children's livelihoods, put their safety at risk and increase child labor. Children's development can be influenced by the environmental safety of their living space. However, neither PE owners nor their residents tend to invest in facilities for their homes because they do not stay there for long periods of time. Owing to inadequate energy infrastructure, children are exposed to the risk of accidents caused by kerosene and firewood. Furthermore, collecting firewood and fetching water increases children's working hours at home, which indirectly affects their learning.

CONCLUSION

This study found that children's quality of life varies between management types, and a disparity in education is also observed. Investigating into estate management types, we found that children living on PEs generally suffer from poorer living conditions and education due to the discrepancy in the social structure of each estate management type to which the children belong.

ACKNOWLEDGEMENTS

I would like to express my gratitude to all the interviewees who spent valuable time in this study. I also express my sincere appreciation for the people who kindly provided me with their support,

assistance, and advice. I would also like to thank my academic advisors for their considerable guidance and encouragement.

REFERENCES

- Asian Development Bank (ADB). 2004. Project completion report on the plantation reform project in Sri Lanka. Asian Development Bank, Colombo, Sri Lanka, Retrieved from <https://www.adb.org/sites/default/files/project-document/69596/pcr-sri-26238.pdf>
- Department of Census and Statistics Ministry of Finance and Planning Sri Lanka (DCS). 2011. Child activity survey 2008/09. Department of Census and Statistics Ministry of Finance and Planning Sri Lanka, Retrieved from https://www.dol.gov/sites/dolgov/files/ILAB/research_file_attachment/Child_Activity_Survey_2008-09_Final_Report_SriLanka.pdf
- Department of Census and Statistics Ministry of Finance and Planning Sri Lanka (DCS). 2013. Classification of administrative divisions by quality of housing. Department of Census and Statistics Ministry of Finance and Planning Sri Lanka, ISBN 978-955-577-823-7
- Herath, D. and Weersink, A. 2009. From plantations to smallholder production, The role of policy in the reorganization of the Sri Lankan Tea Sector. *World Development*, 37 (11), 1759-1772, Retrieved from DOI <https://doi.org/10.1016/j.worlddev.2008.08.028>
- Ministry of Plantation Industries (MPI). 2013. Statistical information on plantation crops 2012. MPI, Government of Sri Lanka, Retrieved from https://plantation.gov.lk/web/images/pdf/publications/plantation_sector_statistical_pocket_book_2012.pdf
- Nihal, S.A. 2011. IMF, World Bank and ADB agenda on privatization, Pillage of plantations in Sri Lanka. Authorhouse, ISBN 1452062609, Bloomington, USA.
- Sen, A. 1992. *Inequality reexamined*. Harvard University Press, ISBN 0-19-828334-2, USA.
- United Nations International Children's Emergency Fund (UNICEF). 2014. All children in school by 2015, Global initiative on out-of-school children, South asia regional study covering Bangladesh, India, Pakistan and Sri Lanka. UNICEF Regional Office for South Asia, Kathmandu, Nepal, Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000226221>
- Wal, S.V.D. 2008. Sustainability issues in the tea sector, A comparative analysis of six leading producing countries. Centre for Research on Multinational Corporations (SOMO), Retrieved from <https://www.somo.nl/sustainability-issues-in-the-tea-sector/>



Agriculture Entrepreneurship on Youth: A Systematic Literature Review

FADHILLA IZZATY SYAUKAT*

*Graduate School of International Food and Agricultural Studies,
Tokyo University of Agriculture, Tokyo, Japan
Email: 13821002@nodai.ac.jp*

KATSUMORI HATANAKA

*Faculty of International Agriculture and Food Studies,
Tokyo University of Agriculture, Tokyo, Japan*

NINA N. SHIMOGUCHI

*Faculty of International Agriculture and Food Studies,
Tokyo University of Agriculture, Tokyo, Japan*

RAMADHONA SAVILLE

*Faculty of International Agriculture and Food Studies,
Tokyo University of Agriculture, Tokyo, Japan*

Received 30 January 2022 Accepted 1 August 2022 (*Corresponding Author)

Abstract Past studies have found that boosting agriculture entrepreneurship education for the youth is one of the critical solutions to the aging agricultural population. Agriculture stakeholders need to provide entrepreneurship training to youth early to develop more agribusiness opportunities and strengthen their entrepreneurial competencies. This paper aims to provide an overview of the development of agriculture entrepreneurship research in the context of youth can become a basis for researchers to conduct future studies on the related topic. This paper reveals the general trend of the subject studied, objectives, methodologies, and research finding through an extensive systematic literature review of past studies on this topic conducted between 2000 to 2021. Out of the total of 1,492 papers found using a combination of the words "Agriculture," "Entrepreneurship," and "Youth," 62 articles passed the screening criteria and were analyzed for this research. This study found that 27% of the reviewed studies focus on university and college students. More than 32% of the studies' objective was to identify the factors influencing youth inclination and intention towards agripreneurship. Subjective norms (external factors) were the determining factors that affect the intention in agripreneurship. Around 39% of the studies used Likert scale questionnaires to obtain data, and more than 55% analyzed the data using qualitative descriptive analysis, 24% used multiple linear regression, and 15% used Theory of Planned Behavior. This paper highlights the need for agripreneurship studies on young farmers using more variative analysis methods to obtain a broader understanding.

Keywords agripreneurship, youth, agribusiness, systematic literature review (SLR), youth inclination

INTRODUCTION

Developing entrepreneurship, especially in the agriculture sector, is vital to overcome the aging agriculture system and increasing youth unemployment. Entrepreneurship is acknowledged as one of the main drivers of economic development by encouraging growth, innovation, technology adoption, and poverty reduction (United Nations, 2013). These are also the same factors important to achieve sustainable agriculture. Entrepreneurship contributes to economic development (Baumol,

1968) and is among the four factors of production in addition to land, labor, and capital. Agriculture entrepreneurship involves creating a product or providing services of value related to agriculture to bring returns on investment and improve livelihoods. Developing agricultural entrepreneurship is necessary to drive human resource productivity in agriculture.

Agripreneurship is not limited to making a farm enterprise profitable but may involve a wide range of agricultural related initiatives with a positive and transformative impact on communities (Mukembo, 2017). The agripreneurship vision emphasizes not on young people return to the farming methods of their parents and grandparents; instead, on the development of value chains, entrepreneurship, and farming as a business. The term agripreneurship fully recognizes the innovation, creativity, resilience, and market orientation implicit in the concept of entrepreneurship (Afande et al., 2015). To create and develop more agribusiness opportunities and strengthen entrepreneurship competencies, entrepreneurship education and training should be applied to the productive age group commonly known as the youth.

There is no universally agreed definition of the youth. According to the United Nations, youth are between 15 and 24 years of age. However, the term differs from one country to another according to the context. In the context of farmers, Indonesia considers farmers aged 19-39 are young farmers, while in European United (EU), young farmers are identified as less than 40 years of age (ENRD in Hamilton et al., 2015).

Unfortunately, it is unclear which youth group (category) should become the focus of agripreneurship studies. Moreover, what did past studies find on this topic? These questions are essential to understand how to increase youth participation in agripreneurship and help determine what suitable interventions are needed for each specific youth group to obtain higher intention towards agripreneurship. To attain the answers, this research deployed the Systematic Literature Review (SLR) methodology and composed the following research questions:

- RQ1: Who are the different subjects of research on agripreneurship?
- RQ2: What objectives and methods are used to analyze agripreneurship in youth?
- RQ3: What factors influence youth inclination, intention, and participation in agriculture?

METHODOLOGY

To answer the research questions, a thorough review of past literature is needed. A Systematic Literature Review (SLR) was selected as the most suitable method which helps map and assesses the existing knowledge and gap on specific issues towards further developing the knowledge base. This review was prepared following guidelines from Petticrew and Roberts (2008). The approach comprises five steps: 1) identifying the research question; 2) identifying relevant studies; 3) study selection; 4) extracting and charting the data; and 5) collating, summarizing, and reporting the results.

This SLR utilized the combination of the words "Agriculture," "Entrepreneurship," and "Youth" for the search in three electronic database sources, namely Google Scholar, Scopus Database, and Science Direct. The authors conducted a review in which only English-written journal articles and conference papers published from 2000 to 2021 were included.

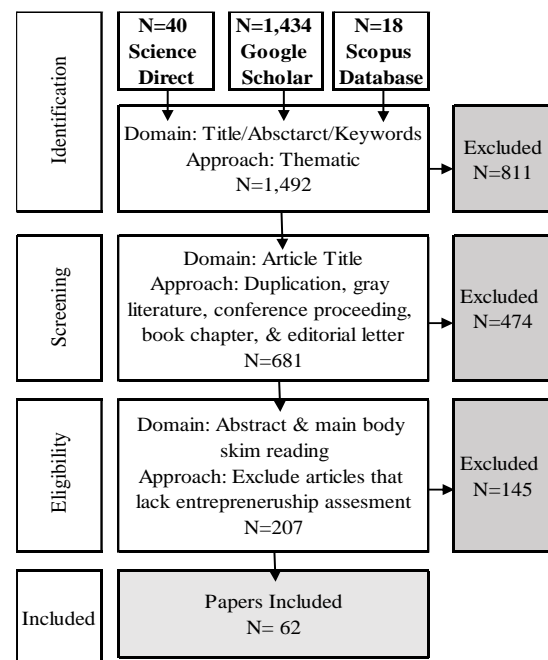


Fig. 1 Screening process of selected literature

This period is selected due to the very limited number of studies found in prior years. Gray literature, conference proceedings, book chapters and editorial letters were excluded.

Articles are then filtered based on abstract reviews match and non-duplication. Then the selected articles were synthesized according to the research question. Figure 1 shows the screening process of the literatures utilized.

SLR RESULTS AND DISCUSSION

General Information of Respondents of the Selected Studies

The majority of researches conducted on agripreneurship in youth was concentrated in Asia, consisting of 64% of the 62 papers, particularly in Malaysia, Indonesia, and India. Africa accounted for 25%, mainly from Nigeria and Kenya. As much as 31.1% of the studies were conducted in 2020, followed by 2019 and 2018 with 14.8%. The subject of the studies was mostly university or college students with 27%, followed by youth in general (people aged 18-39 in the target area of the reviewed study), young farmers, participants of extension programs or training, and vocational school or high school students. Only ten studies targeted young agripreneurs. Table 1 collates the number of selected studies based on their objectives and the subjects targeted. Papers using secondary data (5 papers) were not included in Table 1.

Table 1 Common objective of research and the subjects targeted (n = 62)

Objective \ Subject	University/ college students	Vocational/ high school students	Youth in general	Young farmers	Program participants	%
Inclination and intention factors towards agripreneurship	8	4	4	1	3	32
Factors influence youth to become agripreneurs	4	0	3	1	0	13
Influence of training towards entrepreneurial intention	1	0	0	0	0	2
Characteristics of agripreneurs	1	0	1	3	0	8
Perception and attitude towards agripreneurship	3	2	5	2	0	19
Affect or evaluation of training	0	0	2	3	6	18
Percentage (%)	27	10	24	16	15	

Note: Multiple answers. Papers using secondary data were not included.

The General Objectives and Methodologies Applied by the Selected Studies

As shown in Table 1, 32% of the reviewed studies' objectives are to identify the factors that influence youth inclination and intention towards agriculture and agripreneurship, followed by the perception and attitude towards agripreneurship. It is frequently stated that young people do not consider agriculture as an attractive source of income. Youth interest in the agricultural sector is decreasing year by year (Ridha et al., 2017).

A study in India (Gangwarand and Kameswari, 2016) interviewed 115 youth from four different villages and confirmed that 85% of its respondents had a neutral attitude towards agriculture as a means of livelihood, while 13% had a negative attitude. Only 0.9% of respondents

had a positive attitude towards agriculture as the primary source of income. This condition, which is common in many other parts of the world, is one of the very reasons why the majority of these studies focus on finding an elaborated explanation to factors influencing inclination and intention towards agripreneurship. Research regarding intention formation is an initial effort towards a broader understanding of entrepreneurship (Liu et al., 2020). Characteristics of successful agripreneurs were also observed to help develop better agripreneurs of the future.

Table 2 Methodology of each reviewed paper

	Methodology applied	Reference of publication	%
Data gathering method	Likert scale questionnaire	Abdullah and Samah, 2014; Afande et al., 2015; Ambad et al., 2021; Baliyan et al., 2020; Das, 2017; Dollisso, 2010; G. Shivacharan et al., 2017; Man, 2012; Mukembo et al., 2020; Nade & Mattee, 2019; Nurlaela et al., 2020; Nor et al., 2015; Nyabam et al., 2018; Ofodile and Ndelekwute, 2015; Olutegbe and Ayodele, 2020; Prihatna et al., 2017; Reyes, 2020; Roma et al., 2020; Sa'adiyah et al., 2019; Sazila et al., 2018; Sher et al., 2017; Yu and Wang., 2019; Zain et al., 2020; Zidana et al., 2020	39
	Questionnaire & interview	Abdullah et al., 2013; Afande et al., 2015; Ajekwe and Ibiameke, 2020; Ambad et al., 2021; Aman et al., 2017; Amadi and Nnodim, 2018; Baliyan et al., 2020; Bednarikova et al., 2020; Dollisso, 2010; Gangwar and Kameswari., 2016; Hilmi, 2021; Kyalo and Teresia, 2013; Man, 2012; Mat Taib et al., 2019; Muiruri et al., 2020; Nade and Mattee, 2019; Nyabam et al., 2018; Saptu et al., 2020; Sazila et al., 2018; Singh and Misra., 2021; Olah and Flora, 2015; Withanage and Damayanthi, 2019; Zain et al., 2020	37
	Focused group discussion	Musa et al., 2021; Nade and Mattee, 2019	3
Data analysis method	Qualitative descriptive analysis	Abdullah et al., 2013; Adeyanju et al., 2020; Afande et al., 2015; Alabi et al., 2019; Amadi and Nnodim, 2018; Aman et al., 2017; Ambad et al., 2021; Ayu and Naully., 2020; Baliyan et al., 2020; Barau et al., 2016; Damayanthi, 2019; Das, 2017; Dash and Kumar, 2017; Dollisso, 2010; Hilmi, 2021; Kyalo, 2013; Muiruri et al., 2020; Nade, 2019; Nor et al., 2015; Novanda et al., 2020; Nyabam et al., 2018; Ommani, 2011; Prihatna et al., 2017; Qureshi et al., 2016; Roma et al., 2020; Samah et al., 2012; Sher et al., 2017; Suzani et al., 2010; Sa'adiyah et al., 2019; Withanage and Ofodile et al., 2015; Yamaguchi et al., 2020; Yunandar et al., 2019; Zidana et al., 2020; Zain et al., 2020	55
	Theory of planned behavior	Abdullah and Samah, 2014; Mukembo et al., 2020; Musa et al., 2021; Novanda et al., 2020; Olutegbe and Ayodele, 2020; Reyes, 2020; Ridha et al., 2017; Suprehatin et al., 2020; Saptu et al., 2020	15
	Push and pull theory	Prihatna et al., 2017; Zidana et al., 2020	3
	Regression & multiple linear regression	Adeyanju et al., 2020; Ayu and Naully., 2020; Bednarikova et al., 2020; Das, 2017; M. Kan et al. 2019; Nurlaela et al., 2020; Nor et al., 2015; Ommani, 2011; Prihatna et al., 2017; Samah et al., 2012; Sher et al., 2017; Suzani et al., 2010; Yamaguchi et al., 2020; Yu and Wang, 2019; Zidana et al., 2020;	24
	Partial least square (PLS) & structural equation modelling	Ambad et al., 2021; Chen and Liang, 2020; Mat Taib et al., 2019; Novanda et al., 2020; Saptu et al., 2020; Suprehatin et al., 2020; Reyes, 2020; Ridha et al., 2017	13
	Factor analysis	Chen and Liang, 2020; Kan et al., 2018; M. Kan et al., 2019; Nade, 2019; Nor et al., 2015; Yu and Wang, 2019	10
	Thematic analysis	Hilmi, 2021; Musa et al., 2021	3
	SWOT analysis	Regmi and Naharki, 2020	2
	Entrepreneurial event model	Olutegbe and Ayodele, 2020	2

Note: Multiple answers. Papers using secondary data were not included.

Research methodology is an essential component of any study that provides the framework based on the whole process. With regard to the study design, almost all the studies reviewed used both qualitative and quantitative methods. Agripreneurship has been studied in several

methodological perspectives based on research type, analytical method, and data collection method. The methodology used to analyze the subjects in each paper is listed in Table 2. There were 24 papers that adopted Likert scale questionnaire to obtain data, sharing 38.7%. The Likert scale that was applied varied from 3-point, 4-point, and 5-point Likert scales. Regression, Partial Least Square (PLS) and Structural Equation Modelling (SEM), and Factor Analysis were common methods utilized to analyze the Likert scale type questionnaires with 24%, 13%, and 10%, respectively.

Factors Affecting Youth Inclination, Intention, and Participation in Agriculture

Entrepreneurial intention is closely related to individual competencies that refer to a willingness to conduct a particular behavior. The intention is an acceptance of a representative relationship between cognitive and conative behavior of individuals to perform a certain act. In comparison, inclination is a habitual attraction to some activity or thing. Intention and inclination are semantically related.

As mentioned earlier, TPB is widely used as the basis to analyze entrepreneurial intentions. Suprehatin et al. (2020) found that in the case of agricultural students, they intend to be agripreneurs only as their secondary job or hobby. However, entrepreneurial activity among agricultural graduates' can be increased if the students are provided with business wisdom, inspiration, and motivation, either through mentorship by entrepreneurs and experts or by emphasizing the importance of business opportunities in the curriculum (Sher et al., 2017).

Suprehatin et al. (2020) found that attitude, subjective norm, perceived behavioral control, and personal characteristics positively influence students' intention to be agripreneurs. Abdullah et al. (2014), who studied agriculture university students' inclination towards agripreneurship in Malaysia, also noted a high score level of behavioral attitude and subjective norm, along with social valuation, in inclination toward agripreneurship. A similar study conducted in Indonesia by Arisandi (2016) cited in Ridha et al. (2016) also suggested that subjective norm factors influence agripreneurial intentions of agricultural university graduates. Ridha et al. (2016), in their study targeting on participants of the Agricultural Young Entrepreneurship Growing Program, also stated that subjective norm or external factor determines the intention in agripreneurship. Subjective norm or external factor refers to the social pressure felt by a person and is highly associated with the expectations of parents, family, teacher/lecturer, and friends. In order to increase the youth's intention towards agripreneurship, society's perception of agriculture itself must also be positively promoted.

In the case of youth in general (not primarily focusing on students), Saptu et al. (2020) acknowledged that attitude towards agripreneurship has the strongest relationship with and effect on agripreneurship intention. Subjective norms did not influence the youths' intention towards agripreneurship. Implying that youths have a personal stance regarding career choice.

This study found similarities among the findings of each research, underlining the importance of perception and external factors that influence the youths' decision to become agripreneurs. However, a broader understanding involving all the stakeholders in developing agripreneurship is needed. Future studies are suggested to incorporate not only qualitative but also quantitative analysis towards as many stakeholders as possible in the chain for agripreneurship development.

CONCLUSION

This study has clarified the three research questions by extracting 62 papers using the SLR method. It is known that agripreneurship, especially among youth, has become a popular topic in the past five years, particularly in Asia, followed by Africa. Past studies mainly focus on highly educated youth, like university and college students, while the youth who needs more attention is the young farmers. This study highlights the need for more research on agripreneurship targeting young farmers to understand what is really needed to help them manage their agribusiness effectively. The common objectives of the selected studies are to identify the factors that influence youth inclination

and intention towards agriculture and agripreneurship. Subjective norms (external factors), along with attitude, are determining factors that affect the intention in agripreneurship. In order for the youth to have a higher intention towards agripreneurship, the perception and attitude of agriculture of their environment; parents, family, teacher/lecturer, and friends, should also be positively promoted. By realizing this fact, the government, extension workers, schools, universities, and other related institutions can provide more appropriate ways to promote agripreneurship for each specific youth group.

It is known that 24 papers, sharing 38.7% of the studies extracted, incorporated Likert scale questionnaires and interviews to obtain data and analyzed it using qualitative descriptive analysis (55%), regression (24%), and TPB (15%). This study underlines the need for a more variative use of analytical methods to achieve a broader understanding of agripreneurship among youth. Past studies mainly focus on qualitative data, which is limited to describing perception but lacks in revealing the facts and reality faced by each stakeholder involved in the development of agripreneurship. Future studies need to utilize both quantitative and qualitative data to achieve a more detailed result. When a broad understanding is reached, it is more feasible to provide the proper intervention needed to increase youth participation in agriculture. The currently available training should also be evaluated to ensure its effectiveness. Securing more youth in agripreneurship will lead to more sustainable agriculture in the future.

ACKNOWLEDGEMENTS

The researchers would like to acknowledge the support from Japan Science and Technology (JST) SPRING, Grant Number JPMJSP2122, in addition to the tremendous support from the committee of the Tokyo University of Agriculture's "*Comprehensive Project for Fostering Advanced Human Resources.*"

REFERENCES

- Abdullah, A.A. and Sulaiman, N.N. 2013. Factors that influence the interest of youths in agricultural entrepreneurship. *International Journal of Business and Social Science*, 4 (3), 288-302, Retrieved from https://ijbssnet.com/journals/Vol_4_No_3_March_2013/31.pdf
- Abdullah, F.A. and Samah, B.A. 2014. Factors influencing inclination toward agriculture entrepreneurship among students in agriculture learning institute. *Asian Social Science*, 10 (2), 273-78, Retrieved from DOI <http://dx.doi.org/10.5539/ass.v10n2p273>
- Adekoya, A.F., Ayuba, I.K. and Sokunbi, G.B. 2018. Employment in agriculture and youth unemployment in the West Africa, A psce approach. *International Journal of Governance and Development*, 5 (5), 122-126, Retrieved from https://www.researchgate.net/profile/Ibrahim-Ayuba-4/publication/334304484_Employment_in_Agriculture_and_Youth_Unemployment_in_the_West_Africa,_A_PSCE_approach/link/s/5d2355ffa6fdcc2462cc4c4a/Employment-in-Agriculture-and-Youth-Unemployment-in-the-West-Africa-A-PSCE-approach.pdf
- Adeyanju, D.F., Mburu, J. and Mignouna, D. 2020. Impact of agricultural programs on youth engagement in agribusiness in Nigeria, A case study. *Journal of Agricultural Science*, 12 (5), 145-154, Retrieved from DOI [10.5539/jas.v12n5p145](https://doi.org/10.5539/jas.v12n5p145)
- Adeyanju, D., Mburu, J. and Mignouna, D. 2021. Youth agricultural entrepreneurship, Assessing the impact of agricultural training programmes on performance. *Sustainability*, 13 (4), 1-12, Retrieved from DOI [10.3390/su13041697](https://doi.org/10.3390/su13041697)
- Afandé, F.O., Maina, W.N. and Maina, M.P. 2015. Youth engagement in agriculture in Kenya, Challenges and prospects. *Journal of Culture, Society and Development*, 7, 4-19, Retrieved from <https://iiste.org/Journals/index.php/JCSD/article/view/22759/22837>
- Ajekwe, C.C.M. and Ibiameke, A. 2020. Entrepreneurship through agriculture in Nigeria. *Business And Management Research*, 9 (1), Retrieved from DOI [10.5430/bmr.v9n1p35](https://doi.org/10.5430/bmr.v9n1p35)
- Alabi, D.L., Alabi, D.L. and Famakinwa, M. 2019. Youth corp members' perception of agripreneurship in Oyo and Osun state. *Nigerian Journal of Rural Sociology*, 19 (2), 79-85, Retrieved from <https://rusan.org.ng/issues/RUSAN-JOURN-2018-787.pdf>
- Amadi, N.S. and Nnodim, A.U. 2018. Role of agricultural education skills in entrepreneurship development in rivers state. *International Journal of Innovative Social and Science Education Research*, 6 (1), 9-8,

- Retrieved from <https://seahipaj.org/journals-ci/mar-2018/IJISSER/full/IJISSER-M-2-2018.pdf>
- Aman, Z., Rahim, A.R.A., Kushairi, A. and Fansuri, E. 2017. Agribusiness entrepreneurial intention among generation y, The role of personality traits. *International Journal of Advanced Biotechnology and Research*, 8 (3), 190-96, Retrieved from https://www.researchgate.net/profile/Ehsan_Fansuree_Surin/publication/326368725_Factors_Influencing_Generation_Y_Towards_Agribusiness_Entrepreneurial_Intention/links/5b4859b045851519b4b49849/Factors-Influencing-Generation-Y-Towards-Agribusiness-Entrepreneurial-Intention.pdf
- Ambad, S.N., Sumin, V., Karia, A., Hakim, T.A. and Gisip, I.A. 2021. Factors influencing intention to become agropreneur among youths. *Jurnal Intelek*, 16 (1), 52-61, Retrieved from DOI <http://dx.doi.org/10.24191/ji.v16i1.363>
- Ambadkar, S. 2019. Increasing opportunities, Advantages and future enhancement in agripreneurship. *International Journal of Researches in Social Sciences and Information Studies*, 2019, 154-56, Retrieved from https://ijrssi.in/upload_papers/0512202010091840%20Sanyukta%20Ambadkar.pdf
- Ayu, S.F. and Naully, M. 2020. Entrepreneurship factor's affecting the youth decision to continue their family farm. *Journal of Physics: Conference Series*, 1542, Retrieved from DOI <http://dx.doi.org/10.1088/1742-6596/1542/1/012052>
- Baliyan, S.P., Mosia, P.A. and Baliyan P.S. 2020. Gender differences in entrepreneurial attitudes and constraints, Do the constraints predict university agriculture graduates' attitudes towards entrepreneurship? *International Journal of Higher Education*, 9 (5), 259-273, Retrieved from DOI <http://dx.doi.org/10.5430/ijhe.v9n5p259>
- Barau, A.A., Yahaya A.A. and Afrad, M.S.I. 2016. Willingness to pursue career in agriculture, A case study of secondary school students in Sokoto metropolis Nigeria. *Bangladesh Journal of Extension Education*, 28 (1&2), 1-11, Retrieved from <https://bjee.com.bd/public/editor/show-journal/160>
- Bednarikova, Z., Bavorova M. and Ponkina, E. 2020. Entrepreneurial intention of agriculture undergraduates in Russia. *Agricultural and Resource Economics: International Scientific E-Journal*, 6 (1), 5-22, Retrieved from DOI <https://doi.org/10.51599/are.2020.06.01.01>
- Chen, C.C. and Liang, C. 2020. Evoking agriculture entrepreneurship, How younger and older farmers differ. *Sustainability*, 12 (17), Retrieved from DOI <http://dx.doi.org/10.3390/su12177005>
- Das, S.K. 2017. Factors influencing for a literate youth to take up agricultural entrepreneurship. *Pratidhwani the Echo*, 6 (1), 1-13, Retrieved from <https://www.thecho.in/files/6.-Santanu-das.pdf>
- Dash, D. and Kumar, B. 2017. Investigative analysis of characteristics and vocational training needs of rural youth in agriculture related areas. *Research Journal of Agricultural Sciences*, 8 (6), 1369-1373, Retrieved from <https://acspublisher.com/journals/index.php/ijee/article/download/4698/4277>
- Dollisso, A.D. 2010. Integrating agricultural entrepreneurship into high school agriculture curriculum. *Journal of Agricultural Education*, 51 (3), 125-133, Retrieved from DOI <http://dx.doi.org/10.5032/jae.2010.03125>
- D'Silva, J.L., Dahalan, D., Zaremohzzabieh Z., Ismail, I.A. and Krauss, S.E. 2020. Socio-demographic differences on youth behavioural intention to engage in agriculture. *International Journal of Academic Research in Business and Social Sciences*, 10 (15), 284-291, Retrieved from DOI <http://dx.doi.org/10.6007/ijarbss/v10-i15/8249>
- D'Silva, J.L., Samah, B.A. and Shaffril, H.A.M. 2012. The march to sustainability of agriculture through contract farming, How will the youth fare? *OIDA International Journal of Sustainable Development*, 3 (11), 59-66, Retrieved from <https://ssrn.com/abstract=2047841>
- Hamilton, W., Bosworth, G. and Ruto, E. 2015. Entrepreneurial younger farmers and the "young farmer problem" in England. *Agriculture and Forestry*, 61 (4), 61-69, Retrieved from DOI <http://dx.doi.org/10.17707 /AgricultForest.61.4.05>
- Heinert, S. and Roberts, T.G. 2018. A profile of exemplary rural agricultural entrepreneurship education programs. *Journal of Agricultural Education*, 59 (3), 291-308, Retrieved from DOI <http://dx.doi.org/10.5032/jae.2018.03291>
- Hilmi, M. 2021. Entrepreneurship in farming, Small-scale farming and agricultural mechanization hire service enterprises in Iraq. *Middle East Journal of Agriculture Research*, 10-52, Retrieved from DOI <http://dx.doi.org/10.36632/mejar/2021.10.1.2>
- Janani, S., Ravichandran, V. and Sujeetha, T.N. 2016. A study on marketing behaviour of rural youth entrepreneurs among seven different ventures. *Journal of Extension Education*, 28 (1), Retrieved from DOI <http://dx.doi.org/10.26725/jee.2016.1.28.5620-5621>
- Kan, A., Kan, M., Doğan, H.G., Tosun, F., Uçum, İ. and Solmaz, C. 2018. Evaluation of young farmers project support program in terms of agri-entrepreneurship in Turkey. *Pakistan Journal of Agricultural Sciences*, 55 (4), 1021-1031, Retrieved from <http://openaccess.ahievran.edu.tr/xmlui/bitstream/handle/20.500.12513/4063/cengizsolmaz-2.pdf?sequence=1&isAllowed=y>

- Kharaishvili, E., Chavleishvili, M., Lobzhanidze, M., Damenia, N. and Sagareishvili, N. 2017. Problems of youth employment in the agricultural sector of Georgia and causes of migration. *International Journal of Economics and Management Engineering*, 11 (10), 2343-2348, Retrieved from DOI <http://dx.doi.org/10.5281/zenodo.1132294>
- Liu, H.C., Liang, C., Chang, C.C., Ip, C.Y. and Liang, C.T. 2021. Optimizing personality traits and entrepreneurial creativity to boost the precursors of social entrepreneurial intentions, Five studies in taiwan. *Journal of Social Service Research*, 47 (1), 10-32, Retrieved from <https://doi.org/10.1080/01488376.2019.1708840>
- Man, N. 2012. Unleashing youth potentials in developing the agricultural sector. *Pertanika Journal of Social Science and Humanities*, 20 (1), 93-106, Retrieved from [http://pertanika.upm.edu.my/Pertanika%20PAPERS/JSSH%20Vol.%2020%20\(1\)%20Mar.%202012/14%20Pg%2093-106.pdf](http://pertanika.upm.edu.my/Pertanika%20PAPERS/JSSH%20Vol.%2020%20(1)%20Mar.%202012/14%20Pg%2093-106.pdf)
- Morris, W., Henley, A. and Dowell, D. 2017. Farm diversification, entrepreneurship and technology adoption, Analysis of upland farmers in Wales. *Journal of Rural Studies*, 53, 132-143, Retrieved from DOI <http://dx.doi.org/10.1016/j.jrurstud.2017.05.014>
- Mubeena, T., Praveena, P.L.R.J., Nagavani, A.V. and Murthy, B.R. 2020. Construction of attitude scale for attracting rural youth towards agri-entrepreneurship. *International Journal of Current Microbiology and Applied Science*, 9 (6), 3106-3111, Retrieved from DOI <http://dx.doi.org/10.20546/ijcmas.2020.906.371>
- Muiruri, M.W., Mathenge, F.R. and Ntale, J. 2020. Management strategies and the performance of youth agri-businesses in Kenya, A case of farm Africa. *Journal of Entrepreneurship and Project Management*, 5 (1), 59-83, Retrieved from DOI <http://dx.doi.org/10.47941/jepm.454>
- Mukembo, S.C. 2017. Equipping youth with agripreneurship and other valuable life skills by linking secondary agricultural education to communities for improved livelihoods, A comparative analysis of project-based learning in Uganda. Ph.D. Dissertation, Kyambogo University, Uganda.
- Musa, S.F.P.D., Idris, D.S.R.P.H. and Haris, N.B.M. 2021. Investigating agropreneurial intention among students in higher learning institution using the theory of planned behaviour. *Pertanika Journal of Social Sciences and Humanities*, 29 (2), 1151-1170, Retrieved from DOI <http://dx.doi.org/10.47836/pjssh.29.2.22>
- Nade, P. 2019. Influence of agricultural training on youth farm entrepreneurial self-efficacy, A study of folk development colleges in Tanzania. *Huria Journal*, 26 (2), 227-249, Retrieved from DOI 10.4314/afrev.v14i1.17
- Nor, N.A.A.M., Masdek, N.R.N.M. and Maidin, M.K.H. 2015. Youth inclination towards agricultural entrepreneurship. *Economic and Technology Management Review*, 10a, 47-55, Retrieved from [http://etmr.mardi.gov.my/Content/ETMR%20Vol.10a%20\(2015\)/Vol10a%20\(6\).pdf](http://etmr.mardi.gov.my/Content/ETMR%20Vol.10a%20(2015)/Vol10a%20(6).pdf)
- Novanda, R.R., Khaliqi, M., Jamil, A.S. and Bakhtiar, A. 2020. Factors affects agricultural entrepreneurial intention of agribusiness students. *IOP Conference Series: Earth and Environmental Science*, 454, 1-7, Retrieved from DOI <http://dx.doi.org/10.1088/1755-1315/454/1/012038>
- Nurlaela, S., Hariadi, S.S. and Raya, A.B. 2020. The role of young farmers group in new media utilization for young horticultural agripreneurs in Yogyakarta special region, Indonesia. *Humanities and Social Sciences Reviews*, 8 (3), 518-526, Retrieved from DOI <http://dx.doi.org/10.18510/hssr.2020.8356>
- Nyabam, S.V. and Ijie, B.A. 2018. Empirical analysis of IITA youth in agribusiness model as a panacea for solving youth unemployment problem in Nigeria. *International Journal of Humanities and Social Studies*, 6 (1), 146-152, Retrieved from <https://www.internationaljournalcorner.com/index.php/theijhss/article/view/139776>
- Ofodile, S.N. and Ndelekwute, S.C. 2015. Agricultural education and training, A panacea for entrepreneurship enhancement for national development. *Knowledge Review*, 33 (3), Retrieved from <https://www.globalacademicgroup.com/journals/knowledge%20review/Ofodile.pdf>
- Olutegbe, N.S., and Ayodele, G.O. 2020. Entrepreneurial orientation of agricultural undergraduates, An assessment of selected universities in Nigeria. *Covenant Journal of Entrepreneurship*, 4 (1), 1-19, Retrieved from DOI <http://dx.doi.org/10.47231/zmnk1170>
- Ommani, A.R. 2011. Social, economic and farming characteristics affecting perception of rural youths regarding the appropriateness of a career in production agriculture. *Australian Journal of Basic and Applied Sciences*, 5 (9), 2269-2273, Retrieved from <http://www.ajbasweb.com/old/ajbas/2011/September-2011/2269-2273.pdf>
- Petticrew, M. and Roberts, H. 2006. *Systematic reviews in the social sciences, A practical guide*. Blackwell Publishing, ISBN 9780470754887, UK.
- Prihatna, K.A. 2017. The effect of aec in shaping entrepreneurial motivation for vocational high school prospective graduates. *Binus Business Review*, 8 (2), Retrieved from <http://dx.doi.org/10.21512/bbr.v8i2.2013>

- Qureshi, S., Sheikh S. and Israr, R. 2016. Application of effectual principles to promote agriculture entrepreneurship, Qualitative study of successful agriculture based ventures in sind, Pakistan. *Pakistan Journal of Social Sciences*, 36 (2), 621-634, Retrieved from <http://pjss.bzu.edu.pk/index.php/pjss/article/view/447>
- Reyes, G. 2020. Agribusiness entrepreneurship intention, Insights from a Philippine agricultural university. *Philippine Academy of Management E-Journal*, 3 (2), 78-94.
- Ridha, R.N., Burhanuddin and Wahyu, B.P. 2017. Entrepreneurship intention in agricultural sector of young generation in Indonesia. *Asia Pacific Journal of Innovation and Entrepreneurship*, 11 (1), 76-89. Retrieved from DOI <http://dx.doi.org/10.1108/apjie-04-2017-022>
- Ringa, S. and Kyalo, T. 2013. Agricultural incentives, Assessment of the relationship between economic stimulus programme and youth entrepreneurship in Kenya. *International Journal of Economics and Finance*, 1 (3), 398-405, Retrieved from http://www.ijssse.org/articles/ijssse_v1_i3_398_405.pdf
- Sa'adiyah, T.A.B.T.H., Mahshar, M., Sulai, N.Y.A., Rosli, F. and Hamzah, N.M. 2019. Factors influencing inclination towards agro-food entrepreneurship among Kelantan youth. *Canadian Social Science*, 15 (5), 48-51, Retrieved from DOI <http://dx.doi.org/10.3968/11046>
- Saptu, M.N.F.W., Ambad, S.N.A. and Sumin, V. 2020. The effect of planned behaviour theory on agropreneurship intention, The moderating role of gender. *Social and Management Research Journal*, 17 (2), 213-240, Retrieved from DOI <https://doi.org/10.24191/smrj.v17i2.10522>
- Sargani, G.R., Zhou, D., Mangan, T. and Rajper, H. 2019. Determinants of personality traits influence on entrepreneurial intentions among agricultural students evidence from two different economies. *European Journal of Business and Management Research*, 4 (5), 1-10, Retrieved from <http://dx.doi.org/10.24018/ejbmr.2019.4.5.105>
- Sazila, N.A.S.N., Abdullah, F.A., Khadri, N.A.M., Sidek, S., Abdullah, F.A., Mat, K., Ayob, M.A. and Rahman, M.M. 2018. The intention level among felda youth to re-migrate from city for livestock entrepreneurship, A preliminary study. *International Journal of Academic Research in Business and Social Sciences*, 8 (6), 566-577, Retrieved from DOI <http://dx.doi.org/10.6007/ijarbss/v8-i6/4258>
- Sher, A., Adil, S.A., Mushtaq, K., Ali, A. and Hussain, M. 2017. An investigation of entrepreneurial intentions of agricultural students. *Pakistan Journal of Agricultural Sciences*, 54 (4), 941-945, Retrieved from <https://pakjasapi.pakjas.com.pk/downloadPaper/2784.pdf>
- Simamora, L. 2015. The role of agriculture based on entrepreneurship, Contributes to economic development. *The 9th Bulletin of Monetary Economics and Banking International Conferences*, November Edition.
- Singh, K. and Misra, M. 2021. Developing an agricultural entrepreneur inclination model for sustainable agriculture by integrating expert mining and ISM-MICMAC. *Environment, Development, and Sustainability*, 23, 5122-5150, Retrieved from DOI <http://dx.doi.org/10.1007/s10668-020-00806-x>
- Suprehatin and Shidiq, M.R. 2020. Determinants of agripreneurial career intentions, Evidence from agriculture students. *Jurnal Management and Agribuisness*, 17 (2), 128-137, Retrieved from <https://doi.org/10.17358/jma.17.2.128>
- Suzani, Z., Mirdamadi, S.M. and Mohamadi, I.M. 2010. The role of agricultural extension on incidence of farmer's entrepreneurial characteristics, Case study of Kermanshah province, Iran. *Euphrates Journal of Agriculture Science*, 2 (3), 117-123, Retrieved from <http://www.ejs-agri.com/uploads/pdf/NewFolder/2/3/24.pdf>
- Taib, H.M., Rahim, A.R.A., Aman Z. and Moslim, R. 2019. Factors influencing students' attitudes to choose agriculture as a prospective career, The moderating role of career prospect. *International Journal of Modern Trends in Social Sciences*, 2 (10), 13-2, Retrieved from <http://dx.doi.org/10.35631/ijmtss.210002>
- Withanage, D.P. and Damayanthi, B.W.R. 2019. Factors influencing the youths' interest in agricultural entrepreneurship in Sri Lanka. *Developing Country Studies*, 9 (12), 32-40, Retrieved from DOI <http://dx.doi.org/10.7176/dcs/9-12-05>
- Wulandari, S.E. and Prajanti, S.D.W. 2018. Strategy for youth interest enhancement as effort of agriculture revitalizational in Klaten regency. *Economics Development Analysis Journal*, 7 (2), 224-234, Retrieved from DOI <https://doi.org/10.15294/edaj.v7i2.24718>
- Yamaguchi, C.K., Stefenon, S.F., Ramos, N.K., Silva dos Santos, V., Forbici, F., Klaar, A.C.R., Ferreira, F.C.S., Cassol, A., Marietto, M.L., Yamaguchi, S.K.F. and Leandro de Borba, M. 2020. Young people's perceptions about the difficulties of entrepreneurship and developing rural properties in family agriculture. *Sustainability*, 12 (21), 1-12, Retrieved from DOI <https://doi.org/10.3390/su12218783>
- Yu, T.L. and Wang, J.H. 2018. Factors affecting social entrepreneurship intentions among agricultural university students in Taiwan. *International Food and Agribusiness Management Review*, 22 (1), 107-118, Retrieved from DOI <https://doi.org/10.22434/IFAMR2018.0032>
- Yunandar, D.T., Hariadi, S.S. and Raya, A.B. 2019. Students' attitude towards agricultural entrepreneurship

- in selected vocational colleges in Indonesia, *Journal of Agricultural Extension*, 23 (2), 147-153, Retrieved from 10.4314/jae.v23i2.15
- Zain, N.M., Abdullah, F.A., Bakar, T.H.S.T.A., Rahman, N.A., Khadri, N.A.M., Chng, H.Y. and Latiff, Z.A.A. 2019. Youths participation on development of entrepreneurship agricultural fresh produce preservation skill training module. *Canadian Social Science*, 15 (7), 40-44. Retrieved from DOI 10.3968/11141
- Zidana, R., Kaliati, F. and Shani, C. 2020. Assessment of youth engagement in agriculture and agribusiness in Malawi, Perceptions and hindrances. *Journal of Entrepreneurship & Management*, 9 (2), 19-28, Retrieved from <http://publishingindia.com/GetBrochure.aspx?query=UERGQnJvY2h1cmVzfC82MDE5LnBkZnwwNjAxOS5wZGY=>



Comparison of Crop Surface Models and 3D Point Clouds by UAV Imagery on Estimating Plant Height and Biomass Volume of Pasture Grass

KE ZHANG

Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

AYAKO SEKIYAMA*

*Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: 45620002@nodai.ac.jp*

HIROMU OKAZAWA

*Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: h1okazaw@nodai.ac.jp*

YURI YAMAZAKI

Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

KIICHIRO HAYASHI

Institute of Material and Systems for Sustainable, Nagoya University, Nagoya, Japan

OSAMU TSUJI

Zukosha Co., Ltd, Obihiro, Japan

MASAHIRO AKIMOTO

Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Japan

Received 8 February 2022 Accepted 8 August 2022 (*Corresponding Author)

Abstract Plant biomass is considered an important parameter for crop management and yield estimation, especially for grassland. Aerial photogrammetric techniques have been used for vegetation data gathering of the areas of dense vegetation fields with high research interest. Recent advances in computer vision include structure from motion and multi-view stereopsis (SfM-MVS) techniques, which can derive 3D data such as digital surface models (DSMs) and orthomosaic from overlapping photography taken from multiple angles. The difference between the DSMs of a planted field and the digital terrain model (DTM) has been referred to crop surface model (CSM). Ever since SfM-MVS has been adopted to derive plant height (PH) and above-ground biomass using CSMs at 2013, this method has become the most explored and verified approach to simulate the structure of crops all over the world. However, the complexity of crop structure is thought to be not well represented in DSMs because the DSMs have only one Z value at each 2D pixel. Besides, lacking a DTM representing the bare ground is another problem when adopting the CSM method. On the other hand, the 3D point cloud where DSMs are derived from UAV may provide the structure information in a faster and more detailed way. This research tested the capability of 3D point cloud in estimating plant height and biomass volume of pasture grass, and compared the results with CSMs. UAV photography were conducted at the experimental field of Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan, 2019. The biomass volume estimated by DSM and point cloud have no significant difference, showing that DSM and point cloud have the same performance at estimating biomass volume of grass. In the case that only the simple value data is required, the point cloud data is recommended.

Keywords biomass volume, CSM, DSM, plant height, point cloud, UAV

INTRODUCTION

Proper planting of biomass fuel plant has become one of the main challenges of carbon neutral. In recent years, attention has been paid to the use of pasture grass as biofuel. Gramineae grass has a vigorous regenerative power and can be cut multiple times a year. Some species can be continuously cultivated for more than five years (Nakagawa et al., 2009). Furthermore, pasture grasses can adapt to most kinds of ground surface environment and provide high yields where the edible crops can hardly grow, which avoids the competition between biofuel and food production.

At the site of grassland management, plant height and biomass production monitoring during the growing stage is one of the most important measurements. In the last decade, with the advancement in new platforms such as unmanned aerial vehicles (UAVs), methods based on remote sensing for biomass production estimation are gathering popularity. As a result of the fusion of UAV remote sensing and digital photogrammetry technology, a flexible and automatic approach of progressing aerial imagery has been developed, which is known as the structure from motion (SfM) technology. Based on the multiple overlapping images, characteristic feature points are detected of which the three-dimensional (3D) coordinated are reconstructed during the bundle adjustment progress afterwards. After the bundle adjustment, a detailed scene geometry made by a sparse point cloud is built and all pixels are used in this step to reconstruct finer scene details. Based on this sparse point cloud, the dense point cloud, orthomosaic and the digital surface model (DSM) are exported. As an intermediate production to construct the DSM, the characteristic of the dense point cloud is that it is not filtered, meaning that it contains all the outliers and noise point (Agisoft LLC, 2013). On the other hand, DSM is exported in a common image format such as *.tif with a particular coordinate system, with the pixel size of more than one centimeter, meaning that one pixel represents the mean value of all 3D points inside it. Furthermore, filters such as noise filter and surface smoothing filter are applied to the DSM, which make the DSM unable to represent the detail of the small features on the ground precisely, such as the leaves of plants (Cubero-Castan et al., 2018).

The difference between the DSMs of a planted field and the digital terrain model (DTM) has been referred to crop surface model (CSM) (Hoffmeister et al., 2010). Ever since Bendig et al. firstly adopted SfM-MVS to derive plant height (PH) and above-ground biomass using CSMs at 2013, this method has become the most explored and verified approach to simulate the structure of crops all over the world. Most studies showed that the plant height estimated by CSMs tend to be lower than the plant height measured on the ground, because of the average and smooth surface of CSMs (Bendig et al., 2014). Based on this background, there is thought to be a possibility that point clouds can represent the plant height of crops more accurately than CSMs.

However, there is no study yet discussing the difference at the performance on estimating plant height and above-ground biomass volume of pasture grass. The objectives of this study are 1) to compare the estimation results of plant height and biomass volume obtained by point clouds and CSMs respectively, and 2) discuss the characteristics of each of them on representing three-dimensional structure of the crop.

METHODOLOGY

The study site was a grass field inside the experimental field of Obihiro University of Agriculture and Veterinary Medicine, Obihiro City, Hokkaido, Japan. The specie of the pasture grass was reed canary grass. The surveys by UAV were conducted weekly from 31st May to 3rd September 2019 (15 times in total), with Phantom 4 Pro (DJI). Before the UAV flights, seven ground control points (GCPs), of which position information was measured using RTK-GNSS (HiperV, TOPCON), were settled all over the experimental field. The flights were carried out automatically by Pix4D Capture (Pix4D). During each flight, the flying height was 50 m above ground. Both the top-overlap and the side-overlap rate were 80%. The ground sampling distance (GSD) of the raw aerial imagery was 1.32 cm. Ground surveys in order to obtain the plant height of the grass were conducted from 17th July to 3rd September (totally 8 times), on the same dates as the UAV surveys. During each time of

the ground surveys, six measuring points were settled all around the grass field and marked with marking tapes which could be seen at the aerial imagery. Sampling of these six measure points was made during every time of the ground survey. A self-made plant height measure was used to obtain the optimal height value of the grasses. According to Bendig et al. (2014), “the PH_{CSM} represents the mean plant height of all pixels in a pixel. As a result, not only the top of the plant, for example the ears, is measured, but also the lower parts, like the leaves. Consequently, the detail of PH_{CSM} is higher than PH_M , because PH_{CSM} contains more than on pixel per plant and, the method of the PH_M reference measurements in the field should be discussed.” Based on this opinion, which is most reasonable, the method of method to measure plant height with tape measure or staff ruler, which has been used in many studies, can defiantly not obtain the obtain value standing for the plant height of a certain the field. In this research, a self-made plant height measure was used to obtain the reference plant height. A sliceable plastic plate (10 cm × 20 cm) was used to determine the proper height of the grass canopy. When measuring, the plate was sliced down from above, until every part of its bottom was touched by the grass leaves. The leaves should be naturally curved instead of being forced bending when the plat has stopped. This method can not only help determine the optimal canopy position, but also help the observer to read the scale efficiently. The height of the grass is usually lower than one meter, meaning that the investigator has to squat down or gravel down to the ground in order to look at the canopy from a horizontal direction.

Fig. 1 shows the workflow of the data processing. The RGB imagery obtained by UAV was progressed using Pix4D mapper (ver 4.6.5, Pix4D) to construct the dense point clouds, orthomosaic, and DSMs, of which coordinate was corrected by GCP calibration. By identifying the measuring points at the orthomosaic, the coordinates of the measuring points were extracted using ArcGIS Pro (ver 2.4.1, Esri). After inputting the coordinates into the Pix4D mapper again, the location of the measuring points was marked at the dense point clouds. The plant height obtained from point clouds (PH_{PC}) was then calculated by subtraction the altitude of the ground surface from the altitude of the grass surface. On the other hand, CSMs were made with ArcGIS Pro by subtraction of the DSM of the field without plants from the DSMs with plants. The plant height obtained from CSMs (PH_{CSM}), which was in other words the CSM value of each measuring point, was then extracted using ArcGIS Pro. Then, both PH_{PC} and PH_{CSM} were compared to the measured value of plant height (PH_M) to evaluate the accuracy of point clouds and CSMs to estimate the plant height of grasses. Finally, the above-ground biomass volume (BV) of the whole grass field instead of the particular measuring points was extracted from point clouds and CSMs (BV_{PC} , BV_{CSM}), respectively, and compared to each other to unravel the characteristics of point clouds and CSMs on estimating above-ground biomass volume of pasture grass. The calculation of BV_{CSM} used the geo-metry function of ArcGIS, and the calculation of BV_{PC} used the Volume Tool of Pix4D mapper.

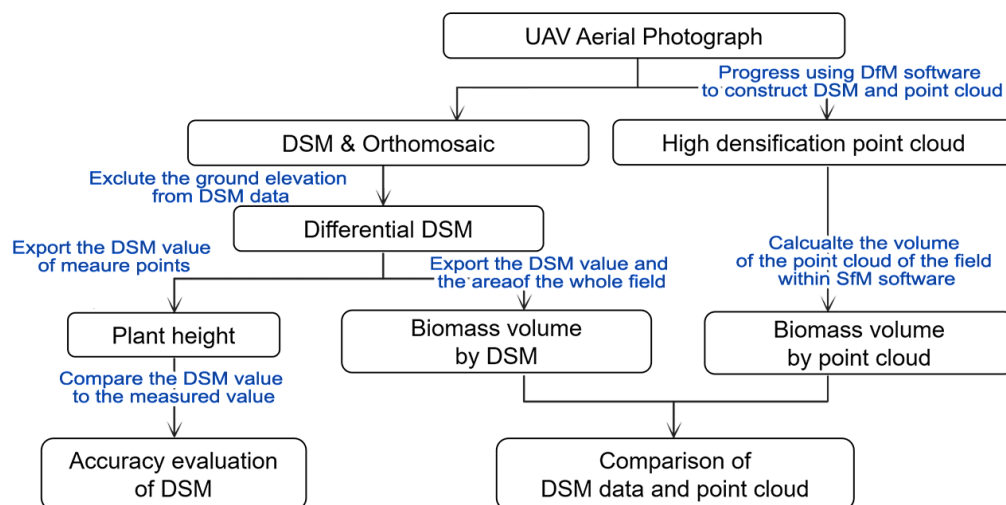


Fig. 1 Workflow of data analysis

RESULTS

1. Time Series of the Plant Height Estimated by Point Clouds and CSMs

Fig. 2 shows the Time series of measured value of plant height (PH_M), plant height obtained from point clouds (PH_{PC}) and plant height obtained from crop surface model (PH_{CSM}). From 17th July to 3rd September, all the three time series lines remained approximately parallel to each other. However, the line of PH_{CSM} stayed lower than the reference line all the time, while the PH_{PC} line was almost laying over the reference line. This indicated that both CSMs and point clouds could reflect the growth trend of grass, while there was a constant difference existing between the plant height estimated by CSMs and the reference value.

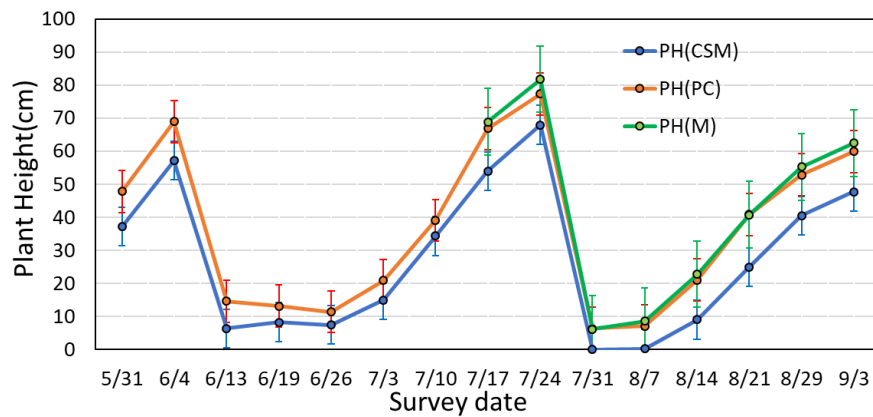


Fig. 2 Time series of PH_M , PH_{PC} and PH_{CSM}

2. Accuracy of Plant Height Estimation by CSMs

Fig. 3 shows the relationship between PH_M and the estimated plant height by CSMS (PH_{CSM}). The number of samples was 48 (6 samples \times 8 times of ground survey). The regression coefficient was close to 1, which suggests the regression line was nearly parallel to the 1:1 line. On the other hand, the intercept was approximately 10, suggesting there was a difference of about 10 cm between PH_M and PH_{CSM} , which stayed stable during the whole survey period since the regression coefficient was near to 1. The R^2 and $RMSE$ were 0.97** and 14 cm, respectively, also showing that PH_{CSM} has the same changing trend, however a stable difference with PH_M . These showed that CSM can represent the changing trend of the plant height of pasture grasses, but has a relatively low accuracy on estimating the value of plant height.

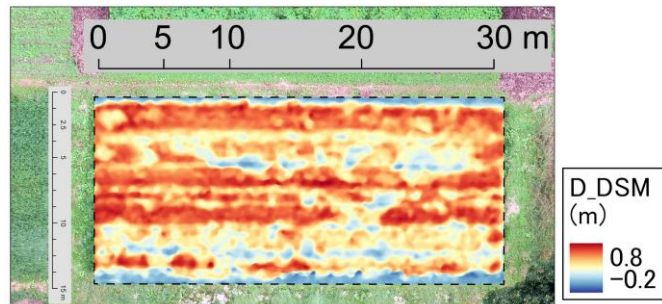
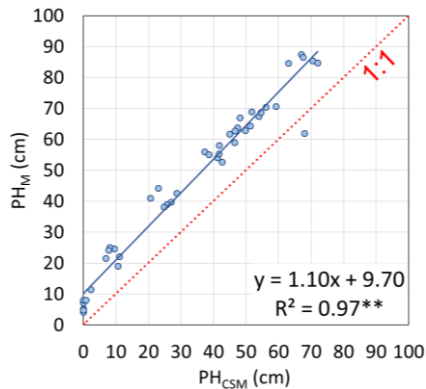


Fig. 3 Relationship between PH_M and PH_{CSM} Fig. 4 CSM map for grass field (2019/7/24)

On the other hand, as shown at Fig. 4, the CSM map could show the growth unevenness clearly by the estimated plant height within ArcGIS.

3. Accuracy of Plant Height Estimation by Point Clouds

Fig. 5 shows the relationship between the measured value of plant height (PH_M) and the estimated plant height by point clouds (PH_{PC}). The regression coefficient and intercept of the regression equation were 1.04 and -0.16, respectively, making the regression line extremely close to the 1:1 line. The coefficient of determination (R^2) and the $RMSE$ were 0.99** and 3 cm, respectively. This result showed that point clouds can estimate plant height of pasture grass with extremely high accuracy with little need for calibration.

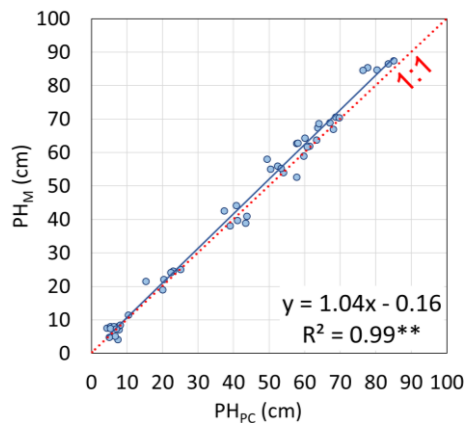


Fig. 5 Relationship between PH_M and PH_{PC}

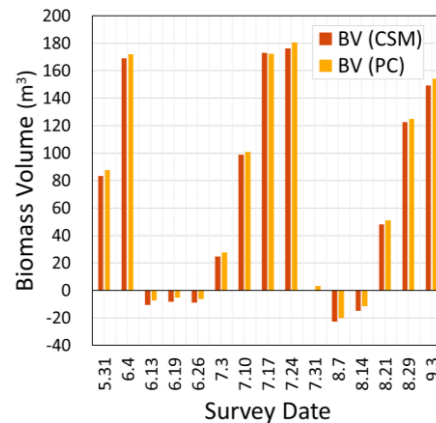


Fig. 6 Comparison of BV_{PC} and BV_{CSM}

4. Comparison of the Above-ground Biomass Volume Estimated by Point Clouds and CSMs

Fig. 6 shows the comparison of BV_{PC} and BV_{CSM} of the whole field during the whole survey period from 31st May to 3rd September. The BV_{CSM} and BV_{PC} of 13th June, 19th June, 26th June, 7th August, and 14th August showed minus value because the DSM used as the bare ground surface had included the remaining grass after the reaping. The result of t-test showed that there was no significant difference between BV_{PC} and BV_{CSM} . This result showed that despite point cloud can estimate plant height of pasture grass with higher accuracy than CSM, it gives the same value of above-ground biomass volume estimation with CSMs.

DISCUSSION

Despite the reference plant height was measured by an improved method and was as accurate as possible, there was still a 13 cm $RMSE$ of the PH_{CSM} of the grassland. It is necessary to realize that there is a problem estimating when estimating plant height using CSMs, which is caused not by the human error or the environmental factors such as the wind, but by the characteristics of the DSM itself. There is a fact that should not be ignored that the airborne laser scanning or the aerial digital photogrammetry were aiming at generating DEMs standing for the basic topographic shape at the first place. The key point of DEM generation using aerial imagery was never about the bumpy terrain or the above-ground objects, but about the smooth terrain. This fact is so important, because it resulted in a critical characteristic of the dense matching algorithm such as SfM-MVS, which are the denoising filter and the smooth filter. Both of these filters can improve the accuracy and quality when constructing terrain models or large-scaled buildings. However, the disadvantage of using these filters is that the small-scaled or low-heighted objects may be smoothed, for example, the leave of crop plants. As long as DSM is still raster data, which represents the ground objects with certain-sized pixels, it has a limit on estimating plant height of crops, because there are spaces between the crop leaves. This is thought to be the inherent weakness of apply remote sensing photogrammetry to agriculture.

Compared with CSMs, point clouds showed much higher accuracy on estimating plant height of grass field. The reason of the high accuracy is considered to be because no smooth filter and

pixel averaging algorithm has been conducted when constructing point clouds. While CSM shows the average height of all the objects of a certain area (for example, one pixel), point cloud shows the particular height of one certain object (for example, the leaf of grass). In other words, point cloud reflects a more detailed height distribution data of the grass field. Therefore, it is considered that point cloud is more qualified than CSM to estimate grass field plant height.

However, on the other hand, when estimating above-ground biomass volume, no significant difference was found between the results obtained by CSMs and point clouds. It is because when calculating the total value of the grass above-ground volume with point cloud, not only the dense points of the canopy that were included, but also the lower parts between the grass leaves, including the ground surface. As the result, point cloud yields the same value as CSM on grass above-ground biomass volume estimation. The spaces between the leaves, which has been found an error factor and should be excluded when estimating plant height, is no longer an error factor when estimating above-ground biomass volume and should be considered in order to increase the accuracy. This led to a conclusion that point cloud is more qualified on estimating plant height of grass than CSM, but has the same accuracy as CSM on estimating above-ground biomass volume.

There have been mainly two purposes for remote sensing at agriculture field, monitoring the current status of the crop land, and predicting the final yield of the crops before harvesting. Before UAV was popularized, the former purpose could not be fully achieved, because neither satellite imagery nor laser scanning was properly suit for the purpose. The ground resolution of satellite imagery, which is usually larger than one meter, is too large for a single crop land. The laser scanning conducted by ground survey is both time and labor consuming, making it almost not realistic for the whole crop field. This is exactly why UAV is so crucial on applying remote sensing to the real agriculture sites. It is more precise than satellite imagery, and more efficient than laser scanning, making it perfectly suit the purpose of current status monitoring of crop lands. For decades, remote sensing has found difficulties on benefiting the farmers directly. With UAV becoming a trustable platform of remote sensing, it is finally possible to help farmers make better management of their own crop land, by not only the traditional CSM data, but also the precise dense point cloud data.

CONCLUSION

In this study, the abilities of dense point clouds and CSMs on estimating plant height and above-ground biomass volume for pasture grass have been validated and compared based on multiple-time surveys. Plant height was monitored by dense point cloud with very high accuracy (RMSE = 3.5 cm), while the plant height monitored by CSMs was consistently lower than the reference value. On the other hand, no significant difference exists between the above-ground biomass volume estimated by dense point cloud and CSMs. These results show that dense point cloud has an advantage on reflecting current status of crops, while has the same accuracy with CSMs on predicting above-ground biomass volume. When the purpose of the UAV survey is to monitor the precise status of the crops or identify the lodging area, point cloud is a better choice of data; while when the purpose is estimating the biomass volume of the whole field with little requirement of details, DSM data provides the estimated value with both accuracy and efficiency.

REFERENCE

- Koppel, P. 2015. Agisoft PhotoScan, Point Cloud accuracy in close range configuration. Koppel Engineering, Retrieved from https://www.agisoft.com/pdf/articles/Paul_Koppel_Agisoft-PhotoScan_case_study_01.pdf
- Bendig, J., Bolten, A., Bennertz, S., Broscheit, J., Eichfuss, S. and Bareth, G. 2014. Estimating biomass of barley using crop surface models (CSMs) derived from UAV-based RGB imaging. *Remote sensing*, 6 (11), 10395-10412, Retrieved from DOI <https://doi.org/10.3390/rs61110395>
- Cubero-Castan, M., Schneider-Zapp, K., Bellomo, M., Shi, D., Rehak, M. and Strecha, C. 2018. Assessment of the radiometric accuracy in a target less work flow using Pix4D software. 2018 9th Workshop on Hyperspectral Image and Signal Processing, Evolution in Remote Sensing (WHISPERS). IEEE, 1-4.

- Nakagawa, H. 2009. Characteristic of tropical grasses for biomass production and the breeding for biofuel feedstocks. *Japanese Journal of Grassland Science*, 55 (3), 274-283, Retrieved from DOI <https://doi.org/10.14941/grass.55.274> Details
- Hoffmeister, D., Bolten, A., Curdt, C., Waldhoff, G. and Bareth, G. 2010. High-resolution crop surface models (CSM) and crop volume models (CVM) on field level by terrestrial laser scanning. *Sixth International Symposium on Digital Earth, Models, Algorithms and Virtual Reality*, 7840, Retrieved from DOI <https://doi.org/10.1117/12.872315>



International Society of Environmental and Rural Development

Philosophy of ISERD:

Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

So, the International Society of Environmental and Rural Development founded in 2010, aims to discuss and develop suitable and effective processes or strategies on sustainable rural development focusing on agricultural and environmental aspects in developing countries. The ultimate goals of the society are to contribute to sustainable rural development through social and economic development in harmony with the natural environment, and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

Purposes of ISERD:

The primary purposes of ISERD are to contribute to sustainable rural development through social and economic development in harmony with the natural environment and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

In order to enhance the realization of the primary purposes of ISERD, the secondary purposes are;

- to facilitate interaction among international, governmental, non-governmental organizations and local communities,
- to hold conferences or symposia on environmental and rural development,
- to edit the International Journal of Environmental and Rural Development,
- to confer some awards based on scientific achievement, research paper or poster presentation, and
- to encourage and develop local awareness concerning sustainable rural development.

Membership:

There shall be two categories of membership.

- (a) Individual
- (b) Organizational

An application for membership of ISERD shall be submitted to the secretariat of ISERD, where is located in the Research Center at Institute of Environmental Rehabilitation and Conservation (Japan) by writing or by other appropriate means.

Also, every presenter who attends the International Conference on Environmental and Rural Development (ICERD) is registered as an Individual Member of ISERD.

Council of ISERD:

The affairs of ISERD shall be governed and managed by the ISERD Council. The councilors are as follows.

President

Prof. Dr. Mario T. Tabucanon, United Nations University Institute for the Advanced Study of Sustainability, Japan

Deputy Presidents

Prof. Dr. Bunthan Ngo, Royal University of Agriculture, Cambodia
Prof. Dr. Anan Polthanee, Khon Kaen University, Thailand
Prof. Dr. Eiji Yamaji, The University of Tokyo, Japan /
Institute of Environmental Rehabilitation and Conservation, Japan

Executive Secretary / Editor-in-Chief of IJERD

Prof. Dr. Machito Mihara, Tokyo University of Agriculture, Japan /
Institute of Environmental Rehabilitation and Conservation, Japan

Managing Editors

Dr. Narong Touch, Tokyo University of Agriculture, Japan
Dr. Shinobu Terauchi, Institute of Environmental Rehabilitation and Conservation, Japan
Dr. Jeeranuch Sakkhamduang, Institute of Environmental Rehabilitation and Conservation /
Association of Environmental and Rural Development, Thailand

Treasurer

Dr. Lalita Siri wattananon, Rajamangala University of Technology Thanyaburi, Thailand

Regional Vice Presidents

Dr. Shafiqullah Rahmani, Ghanzni University, Ministry of Higher Education, Afghanistan
Prof. Dr. Barry N. Noller, The University of Queensland, Australia
Prof. Dr. Sinisa Berjan, Embassy of Bosnia and Herzegovina in Japan /
University of East Sarajevo, Bosnia and Herzegovina
Dr. Buntong Borarin, Royal University of Agriculture, Cambodia
Prof. Dr. Ping Li, Institute of Grassland Research, China
Prof. Dr. Dieter Trautz, Osnabrück University of Applied Sciences, Germany
Dr. Sri Wahyuni, Islamic University of Riau, Indonesia
Dr. Kasumi Ito, Nagoya University, Japan
Prof. Dr. Nang Hseng Hom, Yezin Agricultural University, Myanmar
Prof. Dr. Junaid Alam Memon, Institute of Business Administration Karachi, Pakistan
Prof. Dr. Regucivilla A. Pobar, Bohol Island State University, Philippines
Dr. Chuleemas Boonthai Iwai, Khon Kaen University, Thailand
Dr. David R. Ader, University of Tennessee, USA
Dr. Nguyen Khoi Nghia, Cantho University, Vietnam

ISERD Secretariat:

Research Center, Institute of Environmental Rehabilitation and Conservation (ERECON)

2987-1 Onoji Machida-shi, Tokyo 195-0064, Japan
Tel/Fax: +81-42736-8972
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

Collaborated with

Association of Environmental and Rural Development (AERD)

93/64 Moo.3, Sinsab Village 2, Bungyeetho Sub-District, Thanyaburi District,
Pathum Thani 12130, Thailand
Tel/Fax: +66-2957-8064
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net



**UNITED NATIONS
UNIVERSITY**

UNU-IAS

**Institute for the Advanced Study
of Sustainability**

All articles and reports published in this journal were accepted through a peer-review process. However, most articles and reports published in this journal were presented at the International Conference on Environmental and Rural Development that was co-organized by United Nations University Institute for the Advanced Study of Sustainability.

