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Infrastructural Systems:
Water Resource Development, Land Reclamation, Road Construction, etc.

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Research article

Research article

Influences of Riparian Land Use on Nitrogen Concentration of River Water in Agricultural and Forest Watersheds of Northeastern Hokkaido, Japan

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Abstract This study examines the relationship between nitrogen concentration in river water and agricultural land use in a large-scale upland farming region, with particular emphasis on the influences of riparian land use in agricultural watersheds on the nitrogen concentration in river water. In 21 watersheds in Northeastern Hokkaido nitrogen concentration was surveyed during normal river flow. Cropland (upland and grassland) accounted for 1% to 88% of each watershed, and forestland for 7% to 98%. The survey was conducted six times during the summer and autumn of 2006 and 2007. There was a close correlation between the percent of cropland in each watershed and nitrogen concentration in river water. Use of land for agriculture was shown to elevate the nitrogen concentration in river water. Next, using the buffering function of ArcGIS software, we set three buffer zones demarcated from the channel centerline outward: BZ_{20}, BZ_{60}, and BZ_{100}. The subscripts indicate the width of the zone in meters, with the riverbank as 0 m. The ratio of percent of forestland in BZ_{20} to the percent of cropland in the watershed was defined as the Land Use Index (*LUI*), and its relationship with nitrogen concentration was investigated. This revealed a strong negative correlation between *LUI* and total nitrogen concentration, a correlation that could be approximated by linear regression. This suggests that even when cropland area accounts for much of a watershed, establishment of much riparian forest can reduce the nitrogen concentration in a river.

Keywords riparian land use, nitrogen concentration, river water, watershed, Hokkaido

INTRODUCTION

Contamination of river water in agricultural watersheds has been evident in Japan since the 1980s. In particular, nitrogen contamination of rivers has become a major problem in Hokkaido. It is known that there is a high correlation between the nitrogen concentration of river water and land use (Tabuchi et al., 1995; Woli et al., 2002 and 2004). Land use is defined as cropland (upland and grassland) or forestland as a percentage of the total watershed area in agricultural regions. Okazawa et al. (2003) showed that rivers in watersheds consisting primarily of upland and grassland in Hokkaido contain a high concentration of nitrate nitrogen and that a large part of excess nitrogen (i.e., nitrogen contained in chemical fertilizer or compost that has not been absorbed during crop growth) discharged by agricultural fields flows into river water via base flow runoff. This high correlation between the nitrogen concentration in river water and agricultural land use in watersheds in upland farming regions highlights the importance of managing land use to protect the quality of river water.

Since the 1980s riparian buffers have attracted interest mainly in North America and Europe as a means of protecting water quality (Johnston et al., 1984; Lowrence et al., 1984; Hill et al., 2000).

Riparian buffer zones are areas surrounding rivers where forests, marshes and vegetation are preserved in order to help reduce the level of nitrogen discharged by agricultural fields through plant nitrogen fixation and denitrification. Many studies have been reported on the preservation of water quality using riparian buffers in Europe and North America, but there are few studies on the same topic conducted in Asia, which is distinguished by Asia monsoon climates.

This study explains the relationship between agricultural land use and the nitrogen concentration in river water in a large-scale upland-farming region in the northeastern part of Hokkaido. In particular, a unique definition of the *LUI* for river basin areas is used to show the relationship between the nitrogen concentration in rivers and land use.

METHODOLOGY

Study site

The hydrological investigation was conducted in the Shamou and Abashiri region of northeastern Hokkaido (N43° 54’ - N43° 56’, E144° 19’ - E144° 21’). In this region, the annual mean temperature is 5.8 ℃, the annual low is -7.9 ℃ (February) and the annual high is 17.6 ℃ (August). The annual mean precipitation is 753 mm/yr, much less than the national mean of 1,700 mm/yr. The mean snowfall during November to March is 373 mm/yr. Soil is mainly peat, volcanic and heavy clay, and most cropland is volcanic ash soil.

From the 1960s until recently the region saw large-scale land development for upland, grassland, pastureland and forestland. Residential plots are scattered. Sugar beets, beans, potatoes and grains are cultivated in the cropland. Riparian buffers of wetland and forestland are maintained along many of the rivers in the eastern part of the region, and the channels of these rivers remain in their natural and meandering condition. In the western part, cropland was developed on a large scale and rivers were straightened from their natural and meandering condition.

River water sampling and water quality analysis

In the Shamou and Abashiri region 36 watersheds were chosen for this study. Near the river mouth in each watershed river discharge observations and water sampling were conducted during normal river flows. The field survey was conducted six times each in August, September and October in 2006 and 2007. Water samples were analyzed for quality in the laboratory in terms of total nitrogen (T-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), ammonium nitrogen (NH_4-N) and total organic nitrogen (TON).

Land use analysis

Land use was analyzed using a 1:25,000 topographic map. GIS software loaded with the topography was used for area determination of cropland, forestland and other land. Table 1 summarizes the land use in each watershed. The percent of cropland ranges from 1% to 88% and that of forestland from 7% to 98%. Cropland and forestland account for the majority of land use in most watersheds.

For the purpose of describing land use for each river, each watershed was divided into three zones. Using the buffering function of ArcGIS software, we set three buffer zones demarcated from the channel centerline outward: BZ_{20}, BZ_{60}, and BZ_{100}. The subscripts indicate the width of the zone in meters, with the riverbank as 0 m. Then, we established the *LUI*, which is derived from Eq. 1 to examine the relation between *LUI* and the nitrogen concentration in river water. The *LUI* is a ratio of the area of forestland in BZ_{20} to the cropland area of the entire watershed.

$$Land\ Use\ Index\ (LUI) = \frac{Forest\ Land\ Area\ in\ BZ_{20m}\ [km^2]}{Cropland\ Area\ in\ the\ Watershed\ [km^2]} \tag{1}$$

Table 1 Characteristics of investigated watershed

No.	Watershed	Area (km^2)	*Landuse (%) Cropland	Forest	Other	River length (km)	River density (km/km^2)
1	Mokoto	166.8	41	56	3	130.1	0.78
2	Mokoto(Upper)	102.6	39	58	3	80.0	0.78
3	Chigusa-mokoto	46.3	39	59	2	39.3	0.85
4	Maruman	42.2	32	66	2	48.3	1.14
5	Onnenai	21.1	36	62	2	16.5	0.78
6	Ukarusyubetsu	10.3	77	18	5	3.0	0.29
7	Urashibetsu	57.7	27	72	1	58.5	1.01
8	Urashibetsu(Upper)	38.8	15	84	1	39.7	1.02
9	Tsutupochi	9.1	86	10	4	6.6	0.73
10	Miwak-kansen	3.3	76	13	11	2.0	0.59
11	Yambetsu	138.9	19	78	2	127.0	0.91
12	Panakusyubetsu	14.1	7	93	0	13.7	0.97
13	Yambetsu(Middle)	61.7	11	88	1	53.7	0.87
14	Yambetsu(Upper)	13.3	1	97	2	12.3	0.92
15	Odono	11.2	28	72	1	8.2	0.73
16	Pon-shibetsu	30.6	3	95	1	32.8	1.07
17	Chuo-kansen	5.0	86	9	4	3.9	0.78
18	Higashi-kansen	3.2	88	7	5	1.5	0.46
19	Uenbetsu	44.0	81	12	8	18.8	0.43
20	Syari	529.5	21	78	2	364.2	0.69
21	Ikushina	73.1	9	90	1	60.7	0.83
22	Ikushina(Upper)	57.0	2	98	0	49.0	0.86
23	Akino	46.4	32	67	1	26.1	0.56
24	Akino(Upper)	9.9	12	87	0	2.8	0.28
25	Toyosato	8.9	11	89	0	2.0	0.22
26	Saruma	45.5	51	47	2	23.5	0.52
27	Syari(Mid)	352.5	16	83	1	242.0	0.69
28	Kakurenosawa	26.3	9	90	0	21.8	0.83
29	Kakurenosama(Upper)	24.5	4	96	0	18.3	0.75
30	Chiesakuetonbi	22.1	44	54	2	7.7	0.35
31	Etonbi	12.9	38	61	1	9.5	0.73
32	Pehmen	16.4	11	89	0	9.8	0.60
33	Syari(Upper)	241.6	6	94	1	169.9	0.70
34	Onnebetsu	50.7	10	89	0	40.9	0.81
35	Umibetsu	14.7	9	91	1	8.6	0.58
36	Makushibetsu	4.2	48	51	1	4.2	1.00

** Land use: the percent of cropland (upland plus grassland), forest and other in each watershed*

RESULTS AND DISCUSSIONS

Mean nitrogen concentration of river water

The nitrogen concentration in river water is shown in Fig. 1 for each watershed as the mean and standard deviation of measurements obtained by six field surveys. The mean, minimum and the maximum T-N concentration are 1.61 mg/L, 0.18 mg/L (at watershed No.22) and 5.80 mg/L (at watershed No.18), respectively. In most watersheds, NO_3-N accounted for a large portion of the T-N. Because rivers near upland have higher concentrations of NO_3-N than concentrations of TON, NH_4-N and NO_2-N (Okazawa et al., 2004), it seemed that the investigated rivers were exposed to NO_3-N runoff from nearby uplands.

Influence of agricultural land use on nitrogen concentration of river water

Fig. 2 shows relationships between percent of cropland in each watershed and concentrations of T-N and NO_3-N in the rivers. The concentrations of T-N and NO_3-N increased with percents of cropland.

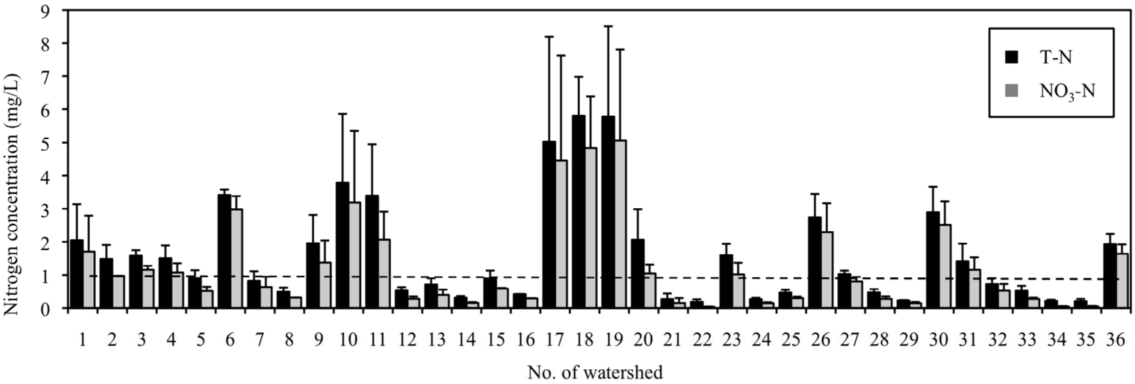
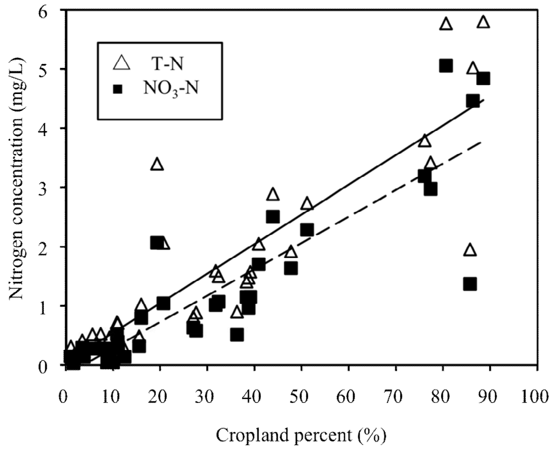
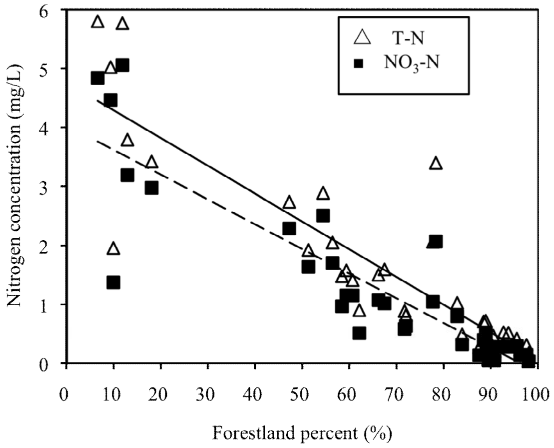


Fig.1 Mean and standard deviation of T-N and NO_3-N concentration
(*Broken line indicates 1 mg/L which is envronmental standard water quality.*)



Solid line (T-N) : $y = 0.05x + 0.05$, $R^2 = 0.75$**
Broken line (NO_3-N) : $y = 0.045x - 0.16$, $R^2 = 0.77$**

Fig.2 Relationship between percent of cropland and nitrogen concentration of river



Solid line (T-N) : $y = - 0.05x + 4.76$, $R^2 = 0.76$**
Broken line (NO_3-N) : $y = - 0.04x - 4.03$, $R^2 = 0.78$**

Fig.3 Relationship between percent of forst-land and nitrogen concentration of river

The correlation between the percent of cropland and the nitrogen concentration is very strong ($R^2 = 0.75$** for T-N and 0.77** for NO_3-N). This suggests that such agricultural land use contributes substantially to the variation in the nitrogen concentration in river water. However, even when the percent of cropland is more than 70%, there are high variations in T-N concentration (1.96-5.80 mg/L) and NO_3-N concentration (1.38-5.06 mg/L), indicating that other factors may affect the nitrogen concentration in river water.

Fig. 3 shows relationship between percent of forestland in each watershed and concentrations of T-N and NO_3-N. A strong inverse correlation between the percent of forestland and the nitrogen concentration demonstrated that forests reduce the concentration of nitrogen in rivers.

Relationship between riparian land use and nitrogen concentration in river water

We examined the percent of riparian forest area in relation to the nitrogen concentration in river water. Fig. 4 shows the relationship between percent of riparian forest area in BZ_{20}, BZ_{60} and BZ_{100} and T-N concentration. Regarding the three buffer zones, T-N concentration decreased with increases in the percent of forestland. Additionally, no significant difference was found between three approximate lines representing the relationship between T-N concentration and the percent of forestland in BZ_{20}, BZ_{60} and BZ_{100}. If the percentages of forestland in BZ_{20} and BZ_{100} are the same, then we conclude that forest area in BZ_{20} can neutralize more nitrogen runoff with less area. Thus, conservation of forest within 20m of the riverbank is important for river water quality control.

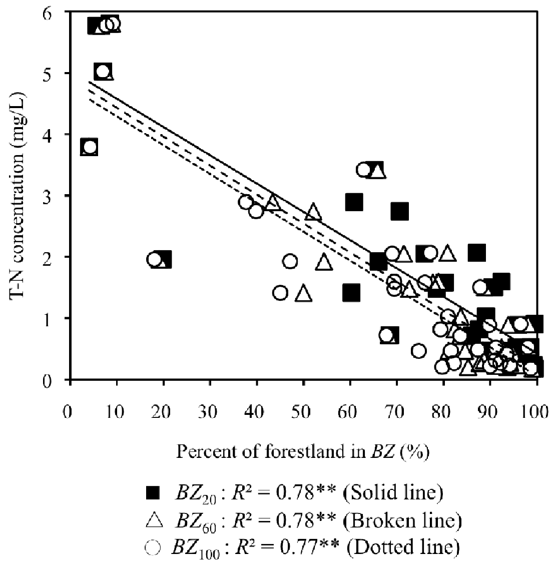


Fig.4 Relationship between forestland percent of BZ_{20}, BZ_{60}, BZ_{100} and T-N concentration

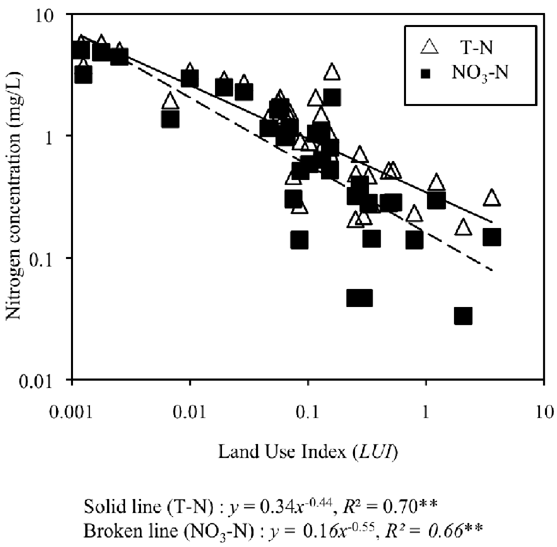


Fig.5 Relationship between *LUI* and N concentration

Land use and river water quality conservation

These results make it clear that conservation and regeneration of forestland in BZ_{20} was important for water quality control in this region. However, the area of cropland outside BZ_{20} varies widely between the watersheds. Even if the forestland in BZ_{20} is well conserved, the buffer zone will not be able to handle all the nitrogen from cropland beyond the zone if that cropland area is too large. For water quality conservation, agricultural land use must be determined while taking into account not only the size of the riparian forest but also the size of cropland area outside the buffer zone. In light of this, we examine that the relation between *LUI* and the nitrogen concentration in river water.

Fig.5 shows the relationship between the *LUI* and the concentrations of T-N and NO_3-N in river water. The investigation revealed a strong negative correlation between *LUI* and nitrogen concentration (R^2=0.70** for T-N and 0.66** for NO_3-N), a correlation that could be approximated by linear regression. Therefore, we found that the nitrogen concentration in river water in this region correlates with the *LUI*. In other words, measures for increasing the *LUI* are necessary to reduce the nitrogen concentration in rivers. The nitrogen concentration will be reduced by reducing the cropland area in the watersheds, or by regenerating forestland in the BZ_{20m}.

From the linear regression formula, we can estimate the minimum *LUI* necessary for reducing the T-N concentration in rivers to 1 mg/L or less. To keep the T-N concentration of rivers in the study region at 1 mg/L or less, we found that an *LUI* of at least 0.09 should be maintained. This means that forestland equivalent to 9% of the cropland needs to be maintained in the riparian land.

CONCLUSION

This study examined the relationship between the percent of cropland and the river nitrogen concentration in large-scale upland farming regions of eastern Hokkaido. The conclusions are: (1) the nitrogen concentration of rivers in 13 out of the 21 watersheds surveyed exceeded 1 mg/L, the maximum level specified in the environmental water-quality standard in Japan, thus confirming the presence of nitrogen contamination in those rivers; (2) as indicated in previous studies, a high correlation between the percent of cropland and the nitrogen concentration in rivers showed that agricultural land use is a major factor contributing to nitrogen contamination. At the same time, a strong inverse correlation between the percent of forestland and the nitrogen concentration demonstrated that forests reduce the concentration of nitrogen in rivers; (3) a correlation between the

LUI and the nitrogen concentration in river water revealed that the land use in river basin areas affects the concentration of nitrogen in rivers. This led to the conclusion that the *LUI* is an important indicator for evaluating the nitrogen concentration in river water. Furthermore, this study showed that in order to prevent the nitrogen concentration from exceeding 1mg/L, the level set as environmentally acceptable, the *LUI* must be kept at no more than 0.09. We conclude that *LUI* is strongly associated with the nitrogen concentration of river water. This suggests that even when cropland accounts for much of a watershed, establishment of much riparian forestland can reduce the nitrogen concentration in a river.

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REFERENCES

Hill, A.R., Devito, K.J., Campagnolo, S., Sanmugadas, K., (2000) Subsurface denitrofication in a forest riparian zone, interactions between hydrology and supplies of nitrate and organic carbon. Biogeochemistry, 51, 193-223.

Johnston, C.A., Bubenzer, G.D., Lee, G.B., Madison, F.W., McHenry, J.R. (1984) Nutrient trapping by sediment deposition in a seasonally flooded lakeside wetland. J. Environ. Qual, 13, 283-290.

Lowrence, R.R., Todd, R.L., Fail, J., Hendricson, J.O., Leonard, J.R. and Asmussen, L. (1984) Riparian forests as nutrient filters in agricultural watersheds. BioScience, 34, 374-377.

Okazawa, H., Inoue, T., Yamamoto, T., Nagasawa, T. and Unoki, K. (2003) Characteristics of stream water quality during rainfall runoff on an upland field area of eastern Hokkaido, Japan. Trans. of JSIDRE, 227, 33-40. (in Japanese)

Okazawa, H., Nagasawa, T., Yamamoto, T. and Inoue, T. (2004) Influence of near-river area's land use on river water quality during rainfall runoff in agricultural watersheds. Participatory Strategy for Soil and Water Coservation, Institute of Environment Rehabilitation and Conservation (ERECON), 39-44.

Tabuchi, T., Yoshino, K., Shimura, M., Kuroda, S., Ishikawa, M. and Yamaji, E. (1995) Relation between land use and nitrate concentration of outflow water from watersheds of agricultural and forest area. Trans. of JSIDRE, 178, 129-135. (in Japanese)

Woli, K.P., Nagumo, T. and Hatano, R. (2002) Evaluating impact of land use and N budgets on stream water quality in Hokkaido, Japan. Nutr. Cycle. Agroecosyst, 63, 175-184.

Woli, K.P., Nagumo, T., Kuramochi, K. and Hatano, R. (2004) Evaluating river water quality through land use analysis and N budget approaches in livestock farming areas. Sci. Total Environ., 329, 61-74.

Research article

Satisfaction of Human Needs as a Tool for the Evaluation of Sustainability through Indicators

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Abstract Inside the current worldwide framework of climate change, economic globalization and population growth, irrigation agriculture faces a series of problems which have to be approached as a challenge to sustainability. To speak about sustainability in irrigation it must be stated that irrigation agriculture is a system of production of goods with the objective of satisfying human needs. From this definition, the concept of sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs achieves full meaning. Developing a methodology of evaluation of sustainability, focused through checking the level of satisfaction of human needs of local populations, may allow for a more complete vision of reality than a mere economic evaluation. In this paper, Maslow's hierarchy of needs is proposed as the structural basis of a methodology of evaluation of sustainability through indicators. Through a survey of farmers in the irrigation area of Terra Cha province of Lugo, northwestern Spain, indicators are developed to monitor the sustainability of their production system. Those indicators are included as ecological factors in a specially-designed algorithm to compare social achievements with the resources used for those achievements. Such a comparison is useful in assessing sustainability through the use of indicators.

Keywords sustainability, irrigation, satisfaction, human needs

INTRODUCTION

During the twentieth century economic growth took countries that already were worldwide economic powers, and some other emerging countries, to a wealth level never before seen in history, the so-called “State of well-being” (Stecher, 2007; Galbraith, 1999). A significant contribution to this economic evolution was the parallel agricultural evolution of the Green Revolution. The Green Revolution required a high level of inputs coming in one way or another from the availability of cheap oil (Gutierrez, 1996). This agricultural evolution allowed substantial cheap food produced by means of worldwide industrial agriculture. This system was able to compensate, through economic mechanisms, periods of shortage in some zones by surpluses from others, to improve the stability of individual diets.

This supply of food needs to the world population had collateral effects. The plowing of new farming land meant deforestation; the overexploitation of soil, its exhaustion; the intensive handling and the lack of protective measures, erosion; the monoculture, increase of plagues; the high level of inputs, salinity and pollution of several kinds; the badly planned extension of irrigation, exhaustion of water courses and aquifers; the wider spread of species and varieties “of high performance”, and loss of genetic diversity (Shiva, 1991). And on the other hand, the economic mechanisms that should have ensured full supply have actually produced strong imbalances between different areas of the planet.

Thus, the cheap availability of food, at least for a percentage of the world population, entailed damage to the environment, to natural resources and to life quality for many people. And there is an implicit threat to the life quality of future generations by the reduction of the productive is the basis for agriculture. Since the global production of a sufficient volume of food has not been translated into satisfying the world population nourishment needs, the present model of food production may be interpreted as an example of private benefit related to public damage. Even more, not even the supply of cheap food (constituting the central argument of industrial agriculture) is happening. Global economic factors such as the rise of biofuel and speculation with commodities doubled the price of basic food in three years, equaling to a backward movement of seven years in the fight against poverty (Daboub, 2008).

Therefore, if there is enough food in the planet for feeding the population but the nourishment needs of that population are not satisfied, and the ability to satisfy them in the future is threatened, why should we go on using that model of production and distribution? If sustainability consists of satisfying the needs of present generations without jeopardizing the capacity of future generations to satisfy theirs (Brundtland, 1987), it would be more suitable, more stable and more lasting, more sustainable in fact, trying to satisfy the nourishment needs of the population sustainably. This is especially so in rural communities, where development is a tactically important issue for their survival (Tolon et al., 2006). By extension, analysis of the level of satisfaction of human needs would be a suitable approach for an evaluation of the sustainability of an agricultural system.

The use of indicators as a tool for sustainability evaluations is widely recognized (Manteiga, 2000). In this paper Maslow's hierarchy of needs (Maslow 1943) is proposed as the basis of a methodology for evaluating sustainability through indicators. Through a survey of farmers in the irrigation area of Terra Cha province of Lugo, northwestern Spain, indicators are developed to measure the sustainability of their production systems. The values of these indicators are used as a way of including ecological aspects in the evaluation. Once implemented in a specific algorithm the results provide a comparison of achievements in the social environment and the resources used. Such information is shown to be a useful methodology.

METHODOLOGY

The irrigation area in Terra Cha Province of Lugo, northwestern Spain (Fig. 1) was chosen for the research because of physical proximity, agricultural relevance and data availability.

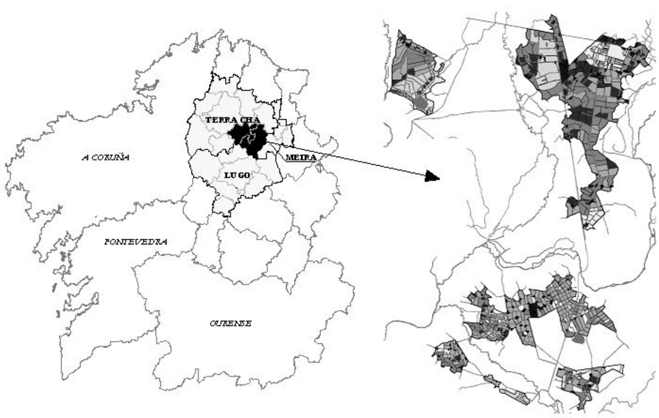

Fig. 1 Map of research zone (Cancela, 2003)

The Terra Cha irrigation area covers 2892 ha divided into three sectors (A Espiñeira, Arneiro, Matodoso). During the fourth quarter of 2009, a survey was conducted of the 192 farmers who live and produce there. The survey included 62 questions with 130 items, gathered in the following groups: ownership and entitlement, farm description, village and farm evolution, factors restricting production, associations, quality and origin of products, attitude towards structural modification, attitude towards change, job and life quality, and attitude and aptitude towards agriculture (Alvarez, 2010).

As a structural basis for the methodology, the hierarchy of Maslow (1943) was adopted. This is shown in Table 1.

Table 1 Hierarchy of needs (Maslow, 1943)

Needs	Description	Elements
Physiological (basic)	Physiological needs, essential to maintain homeostasis (related to the health of the individual)	Breathing Drinking Eating Sleeping Eliminating residues
Safety	Born from the desire of the individual to feel safe and protected	Physical safety Security of employment Security of income and resources
Social recognition	Related to the emotional development of the individual	Association Participation Acceptance
Self-esteem	Related to the way in which the occupation of the individual is recognized	Recognition from others in terms of respect, status, prestige and power
Self-fulfillment	Morality, creativity, spontaneity, problem solving, lack of prejudice, acceptance of facts	The individual arrives to this category when all the other levels have been reached and completed

For these categories the development of significant indicators for each was established by the questions in the survey, with the kind and number of answers indicating their value. Then two concepts are considered: on one side, ecological footprint, described as "a measure of the load imposed by a given population on nature. It represents the area of the Earth's surface necessary to sustain levels of resource consumption and waste discharge by that population" (Wackernagel and Rees, 1996); on the other side, carrying capacity, described as "the amount of productive land required to support a region's population indefinitely at a given material standard" (Rees, 1992). Regional and global values of both concepts are used to develop a further pondering factor applied to the indicators. Also, an algorithm was constructed according to Maslow's hierarchy to provide a tool to interpret the results (Fig. 2).

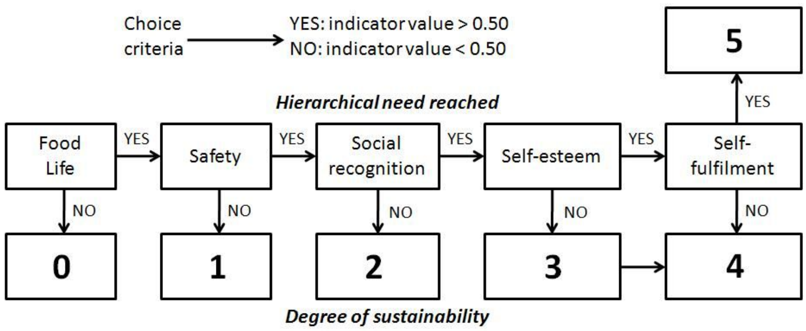

Fig. 2 Algorithm to evaluate the degree of sustainability

The algorithm to evaluate the degree of sustainability of the system follows the hierarchy of Maslow through a YES/NO decision path, with the threshold value fixed at 0.50. This number becomes a reference level assuming that reaching the satisfaction of a certain need for at least half the population allows to consider it satisfied enough. Also, the achievement of a higher step in the hierarchy means a higher degree of sustainability. Reaching a level of 5 in the algorithm would mean full sustainability (high achievements with small consumption of resources), while numbers around 2-4 provide relative levels of sustainability (low, medium or high). Values of 0-1 mean full unsustainability (low achievements with big consumption of resources).

RESULTS AND DISCUSSION

After processing and reviewing the survey, the indicators were obtained according to their representativeness of the given category, and they are shown in Table 2 together with their respective values.

Table 2 Categories, indicators and values of them

Categories (needs)	Indicators	Value (%)
Physiological (basic)	% of available income not spent in nourishment	82.32
Safety	% of population actively employed	93.96
Social recognition	% of participants in associative groups	16.13
Self-esteem	% of farmers satisfied with their job	47.36
Self-fulfillment	% of people satisfied with their life and hopes for the future	40.44

The factors which include the ecological aspect into analysis use the following values, obtained from the research of Martin Palmero (2004):

- Ecological footprint (regional): 7.01 ha per capita
- Carrying capacity (regional): 1.25 ha per capita
- Carrying capacity (global): 2.15 ha per capita

With these values we are able to compare the requirements of productive land for the life standard of the population in the region with two different values of available resources per capita: the regional value (which refers to the local availability of resources) and the global value (which considers the possibility of importing matter and energy and exporting waste). To make this comparison, we build the following ratios, obtaining the subsequent pondering values in so much per one:

- Carrying capacity (regional) / ecological footprint (regional): 0.18
- Carrying capacity (global) / ecological footprint (regional): 0.31

Table 3 Pondered values of indicators and degrees of sustainability reached

Categories (needs)	Indicators	Value (unpondered)	Value (regionally pondered by 0.18)	Value (globally pondered, by 0.31)
Physiological (basic)	% of available income not spent in nourishment	0.82	0.15	0.25
Safety	% of employed people on active population	0.94	0.17	0.29
Social recognition	% of participants in associative groups	0.16	0.03	0.05
Self-esteem	% of farmers satisfied with their job	0.47	0.08	0.15
Self-fulfilment	% of people satisfied with their life and hopes for the future	0.40	0.07	0.12
Degree of sustainability (through algorithm)		2	0	0

In Table 3, the values of indicators, all of them also transformed to so much per one, are given in three ways: without ecological inputs, and modified by regional and global pondering values. The degree of sustainability obtained using the algorithm in Fig. 2 allows comparison between the results using ecological / sustainability considerations.

As it can be seen in Table 3, the values of indicators decrease greatly once they are pondered considering local and global carrying capacities. Also, following the algorithm in Fig. 2, a degree of sustainability of 2 (low relative sustainability) is achieved by using the unpondered values of indicators; however, once we use the pondered values of indicators, either locally or globally pondered, the degree of sustainability achieved becomes 0.

CONCLUSION

The hierarchy of Maslow, used as a framework, allows a structured system of sustainability indicators to be developed. The values of these indicators, which include factors that reflect environmental aspects of the system under study, reveal that the achievements of a society may be reached at an unreasonable environmental cost. Sustainability appears very hard to reach once the hidden costs of producing goods and/or services are shown. From this basic methodology, new versions with more sensitivity and features can be developed to obtain an improved methodology of evaluation of sustainability through indicators.

REFERENCES

Alvarez, C.J. (2010) La opinion de los agricultores gallegos sobre su desarrollo. Personal presentation.

Brundtland (1987) Our Common Future. Oxford University Press, Oxford, UK.

Cancela, J.J. (2003) Gestion integrada del agua en la cuenca alta del rio Miño. Ph.D. thesis. University of Santiago de Compostela, Spain.

Daboub, J.J. (2008) Challenges for a new Asia. Lee Kuan Yew School of Public Policy, Singapur.

Galbraith, J.K. (1999) La sociedad opulenta. Altaya ed., Barcelona, Spain.

Gutierrez, J.A. (1996) La revolucion verde, solucion o problema?, in Suttcliffe, B. (coord.), El Incendio Frio. Hambre, alimentacion y desarrollo, 231-245.

Manteiga, L. (2000) Los indicadores ambientales como instrumento para el desarrollo de la política ambiental y su integración en otras políticas. Estadística y Medio Ambiente, 75-87.

Martin Palmero, F. et al. (2004) Desarrollo sostenible y huella ecologica. Una aplicacion a la economia gallega. Netbiblo ed. A Coruña, Spain.

Maslow, A.H. (1943) A Theory of Human Motivation. Psychological Review, 50, 370-396.

Rees, W. (1992) Ecological footprints and appropriated carrying capacity: what urban economics leaves out. Environment and Urbanisation, 4 (2), 121.

Shiva, V. (1991) The violence of the Green Revolution. Third World Agriculture, Ecology and Politics, Zed Books, London, UK.

Stecher, J.D. (2007) Existence of approximate social welfare. Social Choice and Welfare, 30(1), 43-56.

Tolon, A., Ramirez, M.D. and De Yllescas, M.I. (2006) Construccion de una red Tematica de Indicadores de Sostenibilidad de procesos de Desarrollo en areas rurales de Europa e Iberoamerica. X Congreso Internacional de Ingenieria de Proyectos, 13-15 Sep., Valencia, Spain.

Wackernagel, M. and Rees, W. (1996) Our ecological footprint: reducing human impact on the Earth. New Society Publications, British Columbia, Canada.

Research article

Adverse Effects of Elevated Ambient Ozone on Yield and Protein Loss of Three Thai Soybean Cultivars

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Abstract Various studies in the past have shown that high ozone concentration significantly decreased yield and nutrition in soybean but there is little information in Thailand. Hence, an examination of the aforementioned problem is needed. The purpose of this study is to know the different adverse effects of elevated ambient ozone concentration on yield and protein content of Thai soybean. The research experiment was conducted during December 2007 to March 2008 at the Field Crops Research Center, Phitsanulok, Thailand. Thai native soybean 3 cultivars; Chiang Mai 60, Sorjor 5 and Srisumrong 1; were planted and covered with open top chamber (OTC) since seedling through maturing stage. The OTC with charcoal filtered and non-charcoal filtered were set to control the O_3 level at three different levels ; at ambient level (32 ± 11.1 ppb), lower (12 ± 10.1ppb) and higher than ambient level (62 ± 10.8 ppb). Results indicated that growth and yield loss at maturing stage obviously occurred in all 3 cultivars under high ambient O_3 concentration by statistical significance. However, we found the different reductions in number of total seed/plant of Chiang Mai60, Sorjor5 and Srisumrong 1, by 37, 28 and 33% respectively when they were exposed to 62 ppb O_3 compared to the lower ambient level. The significant reduction by 14% in plant height appeared in only one cultivar, Sorjor 5. The parallel result was shown in protein content; Sorjor5 cultivar showed the most sensitive to high O_3 concentration in protein content reduction by 2.3% but consistent effect was not found in Chiang Mai 60 and Srisumrong 1. The overall results in the study conclude that long-term high O_3 exposure caused different adverse effects in among 3 Thai soybean cultivars. Sorjor5 seems to be more an ozone-sensitivity cultivar than the other cultivars.

Keywords ozone, Thai soybean, open top chamber, yield, protein

INTRODUCTION

Tropospheric ozone (O_3) is one of the main pollutant gasses that cause air pollution. Source of O_3 in troposphere is from a complex, photochemically induced reaction between the hydrocarbons and nitrogen oxides released from motor vehicle exhaust (Manning and Feder, 1976). Many studies have shown that average concentrations of O_3 in many regions have increased, the changes may come about from climate changes and human-emitted precursors (Mohnen et al., 1993; Oltmans et al., 2006). It was anticipated that many factors will contribute to O_3 increase of 20-25% between 2015 and 2050 and 40-60% by 2100 (Mohnen et al., 1993; Singh et al., 2010).

In addition, O_3 which is a powerful oxidizing agent, is responsible for more damage to vegetation than any other air pollutant. Consequently, crop yield reduction caused by tropospheric O_3 is well known (Ostromsky et al., 2001; Singh et al., 2010). Exposure of plants and crops to O_3 usually results in reduction of yield and loss of physiological functions. It was estimated that O_3, alone or in combination with other pollutants, accounts for approximately 90% of air pollution induced crop loss in U.S (David et al., 1994). Hence, among pollutants, tropospheric O_3 is one of the important species that has received considerable attention.

Soybean is one of the economic crops known for its sensitivity to O_3 (Miller et al., 1994). It has been estimated that soybean yields are suppressed by about 10% by 50 ppb O_3 concentration (seasonal mean 7h daily concentration) (Heagle, 1989). The ambient concentration of O_3 in central areas of Thailand is around 20-30 ppb and some supplemental factors can push this level to be 50-80 ppb (Pollution Control Department of Thailand, 2008), which is high enough to cause adverse effects on many components of the ecosystems including crop production in Thailand.

However, the possible adverse affects of O_3 elevation to agricultural crops especially soybean nutrition and production in Thailand is not well understood. Thus, in this study we carried out the experiment to evaluate and understand how elevated O_3 concentrations affect growth and yield of some Thai soybean cultivars.

METHODOLOGY

Site and experimental design

Thai soybean (Glycine max (L.) Merr.) 3 cultivars - Chiang Mai 60, Sorjor 5 (SJ5) and Srisumrong 1 - were planted in an open top chambers at the Phitsanulok Field Crops Research Center, Phitsanulok Thailand during December 2007 to March 2008.

Three replications of Randomized Complete Block Design (RCBD) were used in three treatments with different levels of O_3 in experiment. At vegetative growth stage - third node (V3) - all three cultivars were exposed to three different O_3 concentration levels for 7 hr exposure (9.00 am - 4 pm) in open top chambers until harvest.

Ozone exposure

Exposure of three cultivars of soybean to different O_3 levels were carried out in a open top chamber. The open top chamber (3 m long, 3 m wide and 2 m high) was constructed from a transparent plastic. Ventilation fans were equipped on the front of the chamber to facilitate air circulation and to equilibrate the temperature difference between inside and outside of the chamber.

Three levels of O_3 concentrations - at ambient level, lower than ambient level and higher than ambient level - were set up. In the ambient chamber (non-charcoal filter; NCF treatment), the air was freely circulated in and out of the chamber without passing through any filter. In the chamber with O_3 lower than ambient level (CF treatment), the air was passed through charcoal filter.

O_3 was produced by O_3 generator (Belle Marketing Co.LTD, Thailand Model OZ-3020) via charcoal filter to control O_3 concentration at above ambient level in CF+O_3 treatment. O_3 concentrations in all chambers were measured by real-time ozone gas detector (BW technologies, Canada).

Yield and protein content determination

Soybean plants and seeds were harvested from the experimental field at harvest stage (95 days). These three cultivars of soybean plant samples were determined of shoot length (height), number of total seed/plant. Protein content of soybean seed was analyzed based on analysis of protein and lipid content by AOAC (1995) method.

Statistical analysis

The growth parameters, grain yield and nutrition value data were analyzed statistically with analysis of variance (ANOVA). Significant difference of parameters were reported at $p<0.05$ by DMRT.

RESULT AND DISCUSSION

Ozone concentration

The O_3 monitoring data from 3 treatments in experiment are summarized in Fig 1. From the O_3 generator in the chambers, the detected O_3 concentrations for 7 hr exposure for each treatment were 12 ± 10.1 ppb for CF, 32 ± 11.1 ppb for NCF and 62 ±10.8 ppb for CF^{+O3}, respectively.

Growth parameter

The results in growth parameter were visibly appearing in significant reduction by O_3 on height in Sorjor 5 (SJ5) at the maturity stage. However, their effects were not sufficient for significant reduction for Chiang Mai60 and Srisumrong 1. The most obvious negative result in height was found at high O_3 concentration in treatment CF^{+O3}; the percentage reduction was found to be approximately 14% when compared to CF treatment (Table 1). These results indicate that high O_3 level (above ambient level) induced height suppression and SJ5 could be considered more susceptible to O_3 than Chiang Mai60 and Srisumrong 1. The total changes in relative between enhanced O_3 concentration and height in 3 cultivars of Thai soybean are shown in Fig.1.

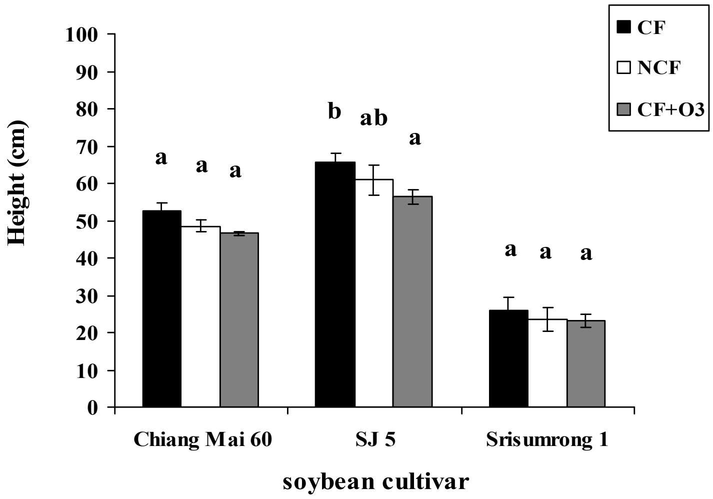

Fig. 1 Effects of O_3 concentrations on height of soybean, 3 cultivars - Chiang Mai 60, Sorjor 5 and Srisumrong 1

The different letters for each parameter indicate a significant difference at $\rho \leq 0.05$. Error bars above each histogram indicated standard deviations (S.D.) observed from samples of each treatment.

Yield parameter

Grain yields were harvested at maturity stage. The parameters - number of total seed/plant - were determined to estimate grain quantity. The response in relative terms between O_3 concentrations (3 levels) and yield in 3 cultivars of Thai soybean are shown in Fig.2. The significant reductions in number of total seed/plant were found in all Chiang Mai60, SJ5 and Srisumrong 1 cultivars and showed the highest reduction in CF^{+O3}. When the significant reductions were considered, we found that the percentage reduction (compared between CF^{+O3} and CF) in Chiang Mai60, SJ5 and Srisumrong 1 were 36%, 28% and 32%, respectively (Table 1).

The results indicate the concomitant relationship between increasing O_3 concentration and decreasing in total seed /plant. In addition, we observed that Srisumrong 1 seems more susceptible to O_3 than other cultivars when considered in the highest reduction in grain yield parameter.

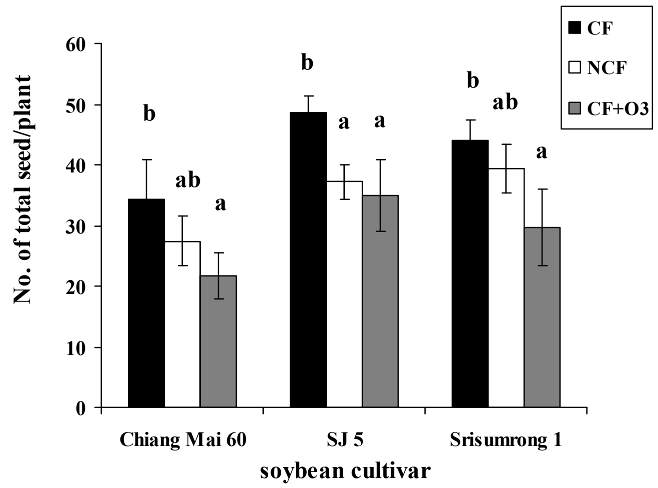

Fig. 2 Effects of O_3 concentrations on yield of soybean, 3 cultivars - Chiang Mai 60, Sorjor 5 and Srisumrong 1

The different letters for each parameter indicate a significant difference at ρ≤0.05. Error bars above each histogram indicated standard deviations (S.D.) observed from samples of each treatment.

Protein content

Protein contents in this experiment were measured at maturing stage (Fig.3). The significant results appeared only in SJ5 cultivar when comparing CF^{+O3} to CF. This significant result was not significant ($p<0.05$, DMRT) when compared to the NCF (ambient level). Percentage of protein content in SJ5 seed indicated that sufficient O_3 concentration at about 62 ± 10.8 ppb (above ambient level) could strongly decrease protein content in SJ5 cultivars. The significant reduction was found to be 2.3% (Table 1).

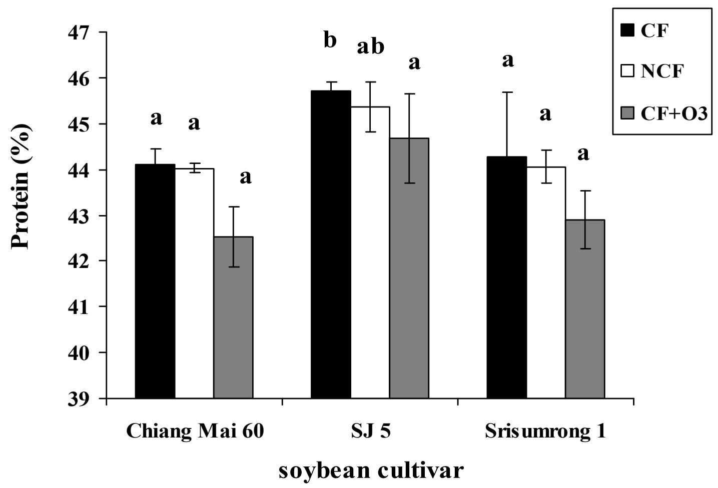

Fig. 3 Effects of O_3 concentrations on protein content of soybean, 3 cultivars - Chiang Mai 60, Sorjor 5 and Srisumrong 1

The different letters for each parameter indicate a significant difference at ρ≤0.05. Error bars above each histogram indicated standard deviations (S.D.) observed from samples of each treatment.

Table 1 Percentage reduction of parameter in 3 cultivars when comparing CF^{+O3} with CF and NCF (in significant results)

Parameter	Cultivar	Treatment			Percentage reduction
		CF	NCF	CF^{+O3}	
Height	Chiang Mai 60	52.5 ± 2.4 ^{a}	48.5 ± 2.5 ^{a}	46.5 ± 3.5 ^{a}	
	*SJ5	65.5 ± 1.6 ^{b}	60.9 ± 3.9 ^{ab}	56.4 ± 3.2 ^{a}	13.8%
	Srisumrong 1	25.8 ± 0.5 ^{a}	23.6 ± 1.9 ^{a}	23.1 ± 1.8 ^{a}	
Number of total seed /plant	*Chiang Mai 60	34.3 ± 6.6 ^{b}	27.5 ± 2.9 ^{ab}	21.7 ± 3.4 ^{a}	36.7%
	*SJ5	48.5 ± 4.0 ^{b}	37.2 ± 2.8 ^{a}	34.9 ± 3.9 ^{a}	28.0%
	*Srisumrong 1	44.0 ± 3.8 ^{b}	39.4 ± 5.9 ^{ab}	29.6 ± 6.3 ^{a}	32.8%
Protein content	Chiang Mai 60	44.1 ± 0.4 ^{a}	44.0 ± 0.2 ^{a}	42.5 ± 1.4 ^{a}	
	*SJ5	45.7 ± 0.1 ^{b}	45.4 ± 0.6 ^{ab}	44.7 ± 0.4 ^{a}	2.3%
	Srisumrong 1	44.3 ± 0.7 ^{a}	44.1 ± 0.9 ^{a}	42.9 ± 0.6 ^{a}	

The symbols (*) indicate a significant result at $\rho \leq 0.05$.

The results obviously show that high O_3 concentration damaged the growth (in height), yield parameters and protein content of soybean examined in this study. However, the results were not as obvious as those observed in all cultivars of soybean. It is interesting that accumulative long-term O_3 exposure (to 62 ± 10.8 ppb) revealed the great significant reduction in whole 3 cultivars in number of total seed/plant. As regards the significant reduction results in all parameters, SJ5 showed the most sensitive cultivar to O_3 in this case.

Other researchers also observed similar results. For example, Miller et al. (1994) studied the effects of O_3 concentrations of 14-83 ppb (12 h daily) on soybean cultivars Coker 6955, Essex and S53-34. The results indicated that O_3 induced visible injury, suppressed net carbon exchange rate, water-use efficiency, accelerated reproductive development, and suppressed growth and yield. In terms of the effects of O_3 on yield loss, we found many consistent results with our investigation results. Studying in soybean at Pakistan Punjab, Wahid et al. (2001) found that O_3 caused significant losses of number of seed per pod and number of pod per plant. Kress and Miller (1983) found a greater reduction of the numbers of filled pods per plant and mean seed weight after O_3 exposure. Heagle et al. (1986) found the yield loss in soybean induced by O_3 in filled pod number per plant and mean seed size. In the field experiment by Kobayashi et al in Japan, they found that fraction of root and dry matter partitioning decreased with increasing O_3 level (Kobayashi et al, 1995). Ariyaphanphitak et al. (2005) describes that the grain growth of cereal is dependent on the production of carbohydrates and the translocation of assimilates from the source organs to the grains. The condition under O_3 exposure may induce the drastic decrease of sucrose and fructan content of the internodes, thus storage of assimilates in the culm could induce insufficient photosynthate supply to the grain and protein production. In addition, the various studies showed that O_3 via leaf then cellular constituents, nucleic acids, purine and pyrimidine derivatives, amino acid group can be oxidized by O_3 (Runeckles and Chevone, 1992). These may be the reason why grain filling and protein content in soybean seed in the research was greatly affected by O_3 exposure at high level. The investigation results show that protein loss due to O_3 exposure was found only in SJ5 cultivar, while the parallel results did not appear in Chiang Mai 60 and Srisumrong 1. Bell and Treshow (2002) reported that three amino acid residuals - tryptophan, cysteine, methionin - are particularly sensitive to O_3. They reported that ozonolysis can open up the pyrrol ring of tryptophan and oxidize the sulphydryl group (-SH) of cysteine and methionine to form disulphide bridge (-S-S-) or sulphoxides; alterations in these amino acids will lead to protein reduction in seed. Therefore, the O_3 tolerance of protein parameter in Chiang Mai 60 and Srisumrong 1 may result from an O_3 tolerance in some or all types of these amino acid residuals.

CONCLUSION

The observation results in these experiments provide the evidences that elevated O_3 concentrations (above ambient level) induced suppression in yield production, growth and protein content in seed of soybean. Seed production/plant was the most susceptible parameter to O_3 among other parameters, while SJ 5 was the most O_3 susceptible cultivar. The results also suggest that soybean planting under O_3 concentration at low levels, showed the best yield and protein production. Thus, the risk management by reducing O_3 emission, preventing further damages, and finding the proper countermeasures are needed and necessary.

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REFERENCES

Ariyaphanphitak, W., Chidthaisong, A., Sarobol, E., Bashkin, V.N. and Towprayoon, S. (2005) Effects of elevated ozone concentrations on Thai jasmine rice cultivars, (Oryza Sativa L.). Water. Air. Soil. Poll., 167, 179-200.

Bell, J.N.B. and Treshow, M. (2002) Air pollution and plant life. John Wiley and Sons, Ltd, UK.

David, T.T., David, M.O., Andrew, A.H. and Lee, E.H. (1994) Effects of ozone on crops. In J.M. David (ed.), Tropospheric Ozone, Lewis publisher, USA.

Heagle, A.S. (1989) Ozone and crop yield. Annu. Rev. Phytopathology, 27, 397-423.

Kobayashi, K., Okada, M. and Nouchi, I. (1995) Effects of ozone on dry matter partitioning and yield of Japanses cultivars of rice (oryza saltiva L.). Agric. Ecosystem. Environ, 53, 109-122.

Kress, L.W. and Miller, J.E. (1983) Impact of ozone on soybean yield. J. Environ. Qual., 12, 276-281.

Manning, W.J. and Feder, W.A. (1976) Effects of air pollutants on plants. In S.L. Allen (ed.), Surface level ozone exposures and their effects on vegetation, Lewis publishers, U.S., 93-156.

Miller, J.E., Booker, F.L., Ficus, E.L., Heagle, A.S., Pursley, W.A., Vozzo, S.F. and Heck, W.W. (1994) Ultraviolet-B radiation and ozone effects on growth, yield, and photosynthesis of soybean. J. Environ. Qual., 23, 83-91.

Mohnen, V.A., Goldstein, W. and Wang, W.C. (1993) Tropospheric ozone and climate change. Air. Waste, 43, 1332-1344.

Oltmans, S.J., Lefohn, A.S., Harris, J.M., Galbally, I., Scheel, H.E., Bodeker, G., Brunke, E., Claude, H., Tarasick, D., Johnson, B.J., Simmonds, P., Shadwick, D., Anlaf, K., Hayden, K., Schmidlin, F., Fujimoto, T. and Cuevas, H.E. (2006) Long term changes in tropospheric ozone. Atmos. Environ., 40, 3156-3173.

Ostromsky, T., Dimov, I., Tzavetanov, I. and Zlatev, Z. (2001) Estimation of the wheat losses caused by the tropospheric ozone in Bulgaria and Denmark. In L. Vulkov, J. Wasniewski and P. Yalamov (ed.), Numerical Analysis and Its Applications, Springer-Verlag, Berlin, Heidelberg, 636-643.

Pollution Control Department (PCD) (2008) http://www.pcd.go.th.

Runeckles, V.C. and Chevone, B.I. (1992) Crop responses to ozone, surface level ozone exposures and their effects on vegetation. In S.L, Allen (ed.), Lewis publishers, USA.

Singh, E., Tiwari, S. and Agrawal, M. (2010) Variability in antioxidant and metabolite levels, growth and yield of two soybean varieties, An assessment of anticipated yield losses under projected elevation of ozone. Agr. Ecosyst. Environ., 135, 168-177.

Wahid, A., Milne, E., Shamsi, S.R.A., Ashmore, M.R. and Marshall, F.M. (2001) Effects of oxidants on soybean growth and yield in the Pakistan Punjab. Environ. Poll., 113, 271-280.

Research article

Ecological Risk Assessment of Using Swine Wastewater for Agriculture

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Abstract The environmental consequences of swine farming are of increasing public concern particularly from waste and waste water. Environmental risk assessment is a key tool to deal with concerns from wastewater reuse by land application.The aims of this study were to evaluate: (i) the diffuse pollution from swine farm, in terms of water quality parameters in effluent and copper contamination due to the application of swine waste water in different Thai soil series; and (ii) the impact of copper in swine wastewater on soil biota activity (soil respiration and earthworm avoidance behavior). The results found that wastewater effluent had average BOD, COD,TDS, Total N, pH and EC at 467, 320, 3950, 0.048 mg/L, 7.8 and 4.5 dS/m, respectively, and average copper concentration of 0.05-0.28 mg/L. Copper contamination was analyzed in two Thai soil series (Roi et (Re) and Namphong (Ng) soil series) after application of the swine wastewater. The results showed that copper level in the Roi et soil series was higher than for Namphong soil series but the copper concentration in leachate from two soil series was the opposite. Soil microbial activity in soil receiving application of swine wastewater was greater than found for the control plot (without applying swine wastewater). The 50% avoidance behavior of earthworm on copper (EC_{50}) in the Namphong (Ng) and Roi et (Re) soil series were 153and 61 mg/kg soil at 7 days. In conclusion, the land application of swine waste water effluence should consider the ecological risks and impact on soil ecosystem from different soil ecosystems as a basis for land management.

Keywords diffuse pollution, swine wastewater, copper, soil series

INTRODUCTION

Swine production has been increasing in many countries including Thailand as pork is a major source of food. However, the environmental consequences of swine farming are of increasing public concern particularly offensive odors emitted from pig manure, urine and waste water. Moreover, an accumulation of copper (Cu) from swine feed in surface soils may have impact on the biological health of soil. Using waste from swine farm on land application has many limitations including risks of ground and surface water contamination by leachate and runoff. Moreover, it is known that the bioavailability and toxicity of Cu in soil varies across different soil types. The concentration and bioavailability of heavy metals in composted organic wastes have negative environmental impacts following land application (Bolan et al., 2003)

Copper is one of the metals found in waste and wastewater from swine production at high concentrations. Copper is an essential element for all organisms at low concentrations but toxic above threshold concentrations. Since heavy metals are not degradable, the accumulation of copper in the soil may have long effects on the plants growing in the soil. It has been reported that excess amounts of copper may inhibit photosynthesis of plants and cause chlorosis of leaves (Liu et al., 2006). The effluent of swine generated in the agricultural properties is known for its high pollutant potential. Usually, the effluents are treated and later applied to the soil as a manure form and in reuse of water

(Miaomiao et al., 2008). However, these applications may occur without a defined rate that considers the soil conditions in the area. As a consequence, it causes problems from diffuse pollution due to the runoff and movement of ions in the profile of the soil. Therefore, ecological risk assessment of swine wastewater uses in Thai soil ecosystem needs to be investigated.

The aims of this study were to evaluate (i) the ecological risk assessment of using swine wastewater from swine farm, in terms of water quality parameters in effluent such as BOD, COD, total nitrogen, nitrate, nitrite, phosphorus, and copper contamination due to the application of swine wastewater in different Thai soil series; and (ii) the impact of copper in swine wastewater on soil biota activity (soil respiration and earthworm avoidance behavior) and plant growth.

MATERIALS AND METHODS

The experiments of this study were divided into 3 parts: (i) swine wastewater characterization; (ii) laboratory based copper contamination due to the application of swine wastewater in different Thai soil series; and (iii) field assessment of the effects of using swine wastewater for land application in sugarcane plot using a ecotoxicological monitoring approach based on soil functionality, chemical soil property and plant growth, and laboratory based on ecotoxicity of copper in swine wastewater on earthworm avoidance.

Chemical analysis

Waste water was collected from the swine farms and analysed for water quality parameters following the standard methods for the examination of water and wastewater (American Public Heath Association, 1980). The experiment for the investigation of copper contamination in two Thai soil series was carried out in a laboratory. The experiments were conducted in polyethylene culture pots, each of capacity 500 ml. The soils series used for this study were from Roi et and Namphong (Sandy) soil series. The physical and chemical properties of soil are shown in Table 1.

The soil samples from the study site between the sugarcane plot using swine wastewater and without using swine wastewater were air-dried and ground well before chemical analysis, such as pH, organic carbon, organic matter, total N, available P, extractable K, Na, and Mg. To determine total copper concentrations, the soil samples were digested by tri-acid mixture (HCl-HNO_3-$HClO_4$). Copper was measured by AAS and data were tabulated as mean ± standard deviation (S.D.) or mean ± standard error (S.E.). Sugarcane's growth and sweetness were measured.

Total heavy metals (Cu) concentrations were analyzed by digesting with HF-HNO_3-$HClO_4$ procedures (Carter, 1993) and then measured by AAS.

Soil biological activity was analyzed by basal respiration with placing 30 g of field moist soil in a 50 ml beaker and incubating the sample for 1 day in the dark at 25^{o} C in an air tight sealed jar along with 10 ml of 1 M NaOH. The CO_2-C evolved was determined after 1 day by titration (Anderson and Domsch, 1990). Basal respiration rate was calculated based on CO_2 evolution over the 1 day period.

The avoidance tests with earthworms were based on the ISO (2005).Each test chamber (replicate) consisted of a plastic box (20 cm in length, 12 cm in width and 5 cm in height) divided in two sides by a card divider inserted transversally in middle position. The control side was filled with 150 g dry weight of two Thai soil series (Roi et (Re) and Namphong (Ng) soil series) without contaminant, also in the other side, the same amount of contaminated soil was placed. The divider was then removed and 10 adult earthworms, previously washed and dried with absorbent paper, were placed onto the middle line. To prevent worms from escaping, the test containers were covered with a lid with a few pierced holes to allow for aeration. The tests were run for a maximum period of 1 week at 27ºC with a photoperiod of 16:8 h light dark.

Statistical analysis

Statistical analysis including calculation of average values, standard deviation (S.D.) and regression was performed on the data obtained in the tests with Microsoft Excel and SPSS 12.0. Test of significance was performed by one-way analysis of variance (ANOVA) by Statistic V8.

RESULTS

The water quality parameters of swine effluent are shown in Table 2. It was found that the swine wastewater effluent had an average BOD, COD ,TDS, total N, total Cu, pH and EC value at 467 mg/L, 320 mg/L, 3950 mg/L, 0.048 mg/L, 0.06 mg/L, 7.8 and 4.5 dS/m, respectively. The results showed that copper were found in Roi et (Re) soil series higher than Namphong (Ng) soil series, but in opposite with the copper concentration in leachate from two soil series (Table 3). The data for Cu accumulation in two Thai soil series (Roi et (Re) and Nampong (Ng) soil series) resulting from swine wastewater application indicated that higher level of Cu was found in Roi et (Re) soil series than Namphong (Ng) soil series (Table 3).

The difference in Cu accumulation between the soil series may be attributed to the difference in soil properties including organic matter content and CEC. The impact of using swine wastewater on sugar cane production was showed in Tables 4, 5 and 6. The results indicated that sugar cane growth with swine wastewater was better than that in the control. Moreover, there was no significant effect in sweetness of sugar cane in both sites (P>0.05) and in addition Cu concentration was slightly higher in effluent treated soil (Table 5). Fig. 1 shows the effects of avoidance percent of earthworm exposure on copper contaminated soil in two Thai soil series (Roi et (Re)). 50% avoidance of earthworm on copper contaminated Roi et (Re) soil serie was lower than that of Namphong (Ng) soil series. This result indicates that the impact of copper on the avoidance of earthworm in the Roi et soil series was higher in the Namphong soil series.

Table 1 The chemical characteristic of two Thai soil series

Parameter	Soil series	
	Roi et (Re)	Namphong (Ng)
pH	5.13	4.29
N (%)	0.03	0.01
P (mg/kg)	4.71	5.63
K (mg/kg)	42.63	0.04
CEC (cmol/100g soil)	9.95	3.96
OM (%)	1.13	0.44
Na (mg/kg)	12.11	1.23
Electrical Conductivity (dS/m)	0.06	0.19

Table 2 Selected water quality of swine wastewater effluent

Parameter	Value
pH	7.8 ± 0.07
BOD (mg/L)	467 ± 50
COD(mg/L)	320 ± 25
Electrical Conductivity(EC,ds/m)	4.5 ± 0.10
TN (%)	0.048 ± 0.004
TDS (mg/L)	3950 ± 120

[a] *values are means ± standard deviations (n = 3).*

Table 3 Copper concentration (mg/kg) in soil and leachate in different soil series after applied swine wastewater

	Cu concentration		% Distribution of Cu in soil and leachate	
	Roi et (Re)	Namphong (Ng)	Roi et (Re)	Namphong (Ng)
Soil (mg/kg)	5.758	4.030	52.6 %	30.6 %
Leachate (mg/L)	5.183	9.154	47.3 %	69.4 %

Cu concentration in swine wastewater was 0.05-0.28 mg/L, Cu concentration in swine manure was 284 mg/kg.

Table 4 The impact of wastewater from swine wastewater on sugar cane production

Plots	Height (metre)	Sweetness (Brix)
Sugar cane Plot (without swine wastewater)	2.786 ± 0.23a	9.311 ± 3.69
Sugar cane Plot (swine wastewater)	3.582 ± 0.089b	9.022 ± 2.11

Value are mean + standard deviation. Mean with the same letter in the column is not significantly different (P>0.05).

Table 5 Copper concentrations in soil at study sites

Plots	Cu (mg/kg)
Sugar cane Plot (without swine wastewater)	1.19
Sugar cane Plot (with swine wastewater)	2.37

Table 6 Impact of wastewater from swine wastewater on soil respiration at study sites

Plots	Soil respiration (mg CO_2/day)
Sugar cane Plot (without swine wastewater)	20.23 ± 0.93^b
Sugar cane Plot (swine wastewater)	30.67 ± 1.53^a

Value are mean + standard deviation. Mean with the same letter in the column are not significantly different (P>0.05).

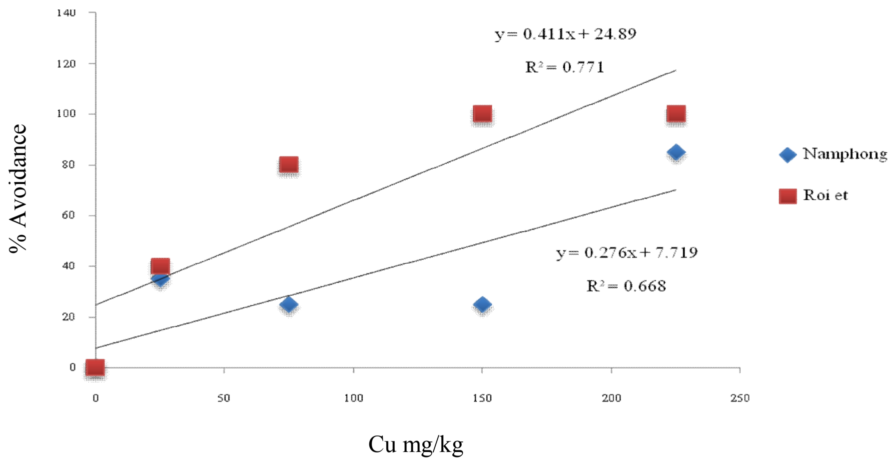

Fig. 1 Avoidance behavior of earthworm exposure to copper contaminated soils applying swine wastewater

CONCLUSION

It was clear that the land application of swine wastewater effluent should be considered from viewpoint of the ecological risk and the impact on soil ecosystem.

Based on the results from short term observation, the benefit of the reusing swine wastewater was more than the impact, as it can provide nutrients that was good for the plants growth and soil quality. The use of wastewater from swine farming did not cause any detrimental effect on soil biota in this short term study. The results from this study also showed that the effect of land application of swine wastewater effluents on soil ecosystem varies with soil types; hence appropriate application levels being suitable for various soil types should be investigated. However, long term effects of reuse swine wastewater for agriculture on soil ecology need to be investigated.

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REFERENCES

Anderson, J.E.P. and Domsch, K.H. (1990) Application of ecophysiological quotients (qCO_2 and qD) on microbial biomass of soil of different cropping histories. Soil Biology and Biochemistry, 22, 251-255.

American Public Heath Association (APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF) (1980) Standard methods for the examination of water and wastewater. American Public Health Association, Washington D.C., USA.

Bolan, N.S., Khan, M.A., Donaldson, J., Adriano, D.C. and Matthew, C. (2003) Distribution and bioavailability of copper in farm effluent. The Science of the Total Environment, 309, 225-236.

Bremner, J.M. and Mulvaney, C.S. (1982) Total Nitrogen. Methods of soil analysis, Part 2, Agronomy Monograph 9, American Society of Agronomy, WI, USA, 595-624.

Carter, M.R. (1993) Soil sampling and methods of analysis. Lewis Publishers, London, UK.

ISO (2005) Standard No. 17512 (Draft) Soil quality - Avoidance test for testing the quality of soils and toxicity of chemicals test with earthworms (*Eisenia andrei*). International Organization for Standardization, Geneve.

Kuo, K. (1996) Phosphorus. In D.L. Sparks (ed.) Methods of soil analysis, Part 3, SSSA Book Ser. 5, SSSA, WI, USA.

Liu, T.F., Wang, T., Sun, C. and Wang, Y.M. (2006) Single and joint toxicity of cypermethrin and copper on Chinese cabbage (Pakchoi) seeds.

Miaomiao, H., Wenhong, L., Liang,X., Wu, D. and Tian, G. (2008) Effect of composting process on phytotoxicity and speciation of copper, zinc and lead in sewage sludge and swine manure.

Natal-da-Luz Tiago, MÓnica, J.B. Amorim, JÖrg RÖmbke and José Paulo Sousa (2007) Avoidance tests with earthworms and springtails: Defining the minimum exposure time to observe a significant response. Ecotoxicology and Environmental Safety, 71, 545-551.

Nelson, D.W. and Sommers, L.E. (1982) Total carbon, organic carbon, and organic matter. In A.L. Page, R.M. Miller and D.R. Keeney (ed.), Methods of soil analysis, Part 2, Chemical and microbiological properties, 539-579. ASA and SSSA, WI, USA.

Schroth, G., Lehmann, J. and Barrios, E. (2003) Soil nutrient availability and acidity. CABI Pub., Wallingford, 93-190.

Schollenberger, C.J. and Simon, R.H. (1945) Determination of exchange capacity and exchangeable bases in soil ammonium acetate method. Soil Sci., 59, 13-24.

Walkley, A. and Black, I.A. (1934) An examination of the Degtareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci., 34, 29-38.

Research article

Using *Azolla Pinnata* for Wastewater Treatment from Poultry Farm

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Abstract Waste water from animal farm especially from poultry industry is one of the sources of non-point source water pollution in Thailand. Plants can be a practical tool for waste water treatment. Aquatic fern (*Azolla pinnata*) has been used to for organic matter, nitrogen and phosphorus removal from waste water and can be good for increase soil fertility. The objectives of this study were to use *Azolla pinnata* for poultry industry wastewater treatment and to assess the potential use of *Azolla pinnata* biomass for increasing fertility of soil resource. The results found that *Azolla pinnata* can reduce BOD of wastewater from slaughter to 41% and produce the biomass of *Azolla pinnata* 90, 167, 245% in 100, 50, 25% dilution of wastewater, respectively. This study demonstrated that *Azolla pinnata* can be taken into consideration as a tool for wastewater treatment from agriculture activities especially suitable wastewater treatment for small poultry farming.

Keywords *Azolla pinnata*, phytoremediation, poultry industry wastewater, soil fertility

INTRODUCTION

The poultry industry is one of the largest and fastest growing agro-based industries in the world. There is an increasing demand for poultry meat mainly due to its acceptance by most societies and its relatively low cholesterol content. The poultry industry is currently facing a number of environmental problems. One of the major problems is the accumulation of large amount of wastes, especially manure and litter, generated by intensive production. The accumulation of these wastes may pose disposal and pollution problems unless environmentally and economically sustainable management technologies are evolved (Bolan et al., 1992). The poultry industry should mitigate environmental consequences associated with air and water quality parameters that are impacted. Therefore, the development of cost-effective technologies for wastewater treatment should be studied.

Azolla, a genus of floating aquatic ferns is distributed throughout tropical and temperate regions of the world (Kitoh et al., 1993). Azolla possesses the ability to utilize atmospheric N_2 due to a symbiosis with the blue-green alga *Anabaena Azollae*, which grows in the cavities of Azolla leaflets. Azolla has been used extensively and effectively for green manure in rice fields instead of chemical fertilizer in Asia. Interest in the use of this plant as a biological filter for the renovation of waste water has increased (Watanabe et al., 1992). Nowadays, poultry production in Thailand has increased and made the treatment of its waste and wastewater an urgent environmental issue. *Azolla pinnata* was chosen as an aquatic plant for the wastewater treatment because of its effeicency in removing organic and nutrient wastes and because the biomass can be used for improves soil fertility.

OBJECTIVES

The objectives of this study were to test the role of *Azolla pinnata* in poultry wastewater treatment and increased soil fertility for sustainable soil resources.

MATERIALS AND METHODS

Test organism

Azolla pinnata used in our experiments was successful cultured under control laboratory conditions at the Ecotoxicology and Environmental Sciences Laboratory, Faculty of Agriculture, Khon Kaen University, Thailand.

Experiment

The experiment was conducted in 2008 using *Azolla pinnata* to treat the wastewater and ran for a 7-d period. Water samples from the poultry industry were collected and analyzed for water quality parameters following the standard methods for the examination of water and wastewater (APHA 1998). Biomass of *Azolla pinnata* was recorded after experiment (Vermaat, 1998).

Laboratory tests were performed in order to examine the efficiency of using A. pinnata to treat the wastewater from poultry industry. Extensive monitoring of the treatment efficiency was performed by collecting weekly samples from the different treatment units. All physico-chemical analyses for pH, COD, BOD, NPK, TSS, dissolved oxygen were performed according to Standard Methods (APHA, 1998). Each pond made of cement occupied 1 m^2 area and was 0.48 m deep. The experimental ponds were inoculated with A. pinnata, at 60 g fresh aquatic fern per container.

The plant growth rate and yield were monitored after the experiment in each pond. The harvested biomass was drained, weighed and dried in an oven at 70^{o}C. The dry matter content was calculated. The dry matter was powdered in a tissue grinder and 0.2 g was used for organic N analysis. As many as 0.1 g of the powder was taken and burned at 550^{o}C for 1 h. The ash was analysed for phosphorus content using the persulfate digestion method (APHA, 1998) followed by the vanadomolybdate colorimetric method (APHA, 1998).

Statistical analysis

Statistical analysis including calculation of average values, standard deviation (S.D.) and regression was performed on the data obtained in the tests with Microsoft Excel and SPSS 12.0. Test of significance was performed by one-way analysis of variance (ANOVA) by Statistic V8.

RESULTS

The water quality parameters of poutry effluent are shown in Table 1. The results showed that *Azolla pinnata* can reduce BOD of wastewater from slaughter to 41% and produce the biomass of *Azolla pinnata* 90, 167, 245% in 100, 50, 25% dilution of wastewater, respectively (Tables 2 and 3).

Table 1 Selected water quality of poultry wastewater effluent

Parameter	Source of water	
	Leachate from chicken manure	Wastewater from slaughter
pH	7.3	7.7
EC (ms/cm)	2.3	1.5
BOD (mg/L)	500	1450
Oil & Grease (mg/L)	0.16	0.12
TKN (mg/L)	63	70
TP (mg/L)	6.48	6.89
SS (mg/L)	20	20
TS (mg/L)	4600	1140
TDS (mg/L)	4580	1120

Table 2 Potential of using A. pinnata for poultry wastewater treatment in BOD reduction

Water Treatment	BOD (mg/L) Before	After	% Change of BOD
Leachate from chicken manure	500±50	400±70	-20%
Leachate from chicken manure +*A. pinnata*	500±50	850±25	+70%
Wastewater from slaughter	1450±50	1050±100	-27.5%
Wastewater from slaughter +*A. pinnata*	1450±50	850±50	-41.37%

Value are mean ± standard deviation. Mean with the same letter in the column are not significantly different (P>0.05). [a] values are means ± standard deviations (n = 3).

Table 3 Biomass production of *A. pinnata* after poultry wastewater treatment

Leachate from chicken maure	Biomass Before	After	Biomass production (%)
100%	40 cell	0 cell	0
50%	40 cell	13 cell	0
25%	40 cell	18 cell	0
Leachate from slaughter	**Biomass Before**	**After**	**Biomass production (%)**
100%	40 cell	76 cell	90%
50%	40 cell	107 cell	167%
25%	40 cell	138 cell	245%

Table 4 Biomass production and nutrient (%K, %P and %N) of *A. pinnata* in waste water treatment

Treatment	%K	%P	%N	% Biomass production
Control	4.63	0.75	2.66	142.67
Azolla in 100	2.43	0.57	1.98	0
Azolla in 50	3.45	1.29	2.50	45.10
Azolla in 25	8.92	0.75	3.51	150.33

Table 5 Potential of using A. pinnata for slaughter wastewater treatment in BOD reduction after 1, 2, and 3 weeks

Treatment	Week 0	Week 1	Week 2	Week 3	% BOD Reduction
100	1325.0 A	1300.0 A	1275.0 A	1325.0 A	30%
100+azola	1325.0 A	1225.0 A	1225.0 A	1225.0 B	27.54%
50	641.67 B	675.00 B	650.00 B	655.00 C	3.06%
50+azola	641.67 B	416.67 C	408.33 C	383.33 D	40.25%
25	416.67 B	350.00 CD	350.00 CD	375.00 D	10.01%
25+azola	416.67 B	266.67 D	241.67 D	233.33 E	44.01%
CV	17.39	8.39	7.48	3.15	
t-test	**	**	**	**	

Value are mean ± standard deviation. Mean with the same letter in the column are not significantly different (P>0.05). [a] values are mean ± standard deviations (n = 3).

From Table 5, the use of *A. pinnata* in wastewater could reduce BOD values compared with control with a significant difference (p< 0.01) in each treatments. BOD values were reduced within the first week and more reduced in Week 3. The use of Azolla in the treatment of wastewater from a chicken farm, 25% and 50% can reduce BOD up to 44% and 40%, respectively**.** From Table 6, the use of *A. pinnata* in wastewater could reduced COD values compared with controla significantly difference (p< 0.01) in each treatment. COD values were significantly reduced in week 3 espectially in wastewater 50% could reduce the COD value at most 87.5%.

Table 6 Potential of using A. pinnata for slaughter wastewater treatment in COD reduction after 1, 2, and 3 weeks

Treatment	Week 0	Week 1	Week 2	Week 3	% COD Reduction
100	5200.0 A	3900.0 A	2925.0 A	3900.0 A	25.00%
100+azola	5200.0 A	2275.0 B	1408.3 B	2816.7 B	45.84%
50	2600.0 B	1950.0 B	812.50 C	1137.5 C	12.50%
50+azola	2600.0 B	845.00 C	715.00 CD	715.00 CD	87.50%*
25	1040.0 C	758.33 C	595.83 CD	595.83 D	31.25%
25+azola	1040.0 C	563.33 C	303.33 D	281.67 D	72.92%
CV	27.9	22.53	26.21	19.47	
t-test	**	**	**	**	

Values are mean ± standard deviation. Mean with the same letter in the column are not significantly different (P>0.05). [a] *values are means ± standard deviations (n = 3).*

CONCLUSIONS

This study showed that *Azolla pinnata* was suitable for the wastewater treatment from chicken industry especially from the slaughter. The results found that *Azolla pinnata* can reduce BOD and COD in wastewater from slaughter and produce the biomass of *Azolla pinnata*. As the wastewater associated high amount of nutrient in experimental can increase the *Azolla pinnata* biomass and accumulate the nutrient. Therefore, biomass can be used for agriculture land to improve soil fertility.

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REFERENCES

American Public Health Association (1998) Standard methods for the examination of water and wastewater. Washington DC, USA.

Becking, J.H. (1979) Environmenttal requirements of Azolla for use in tropical production. Nitrogen and Rice, IRRI, Philippines, 348-370.

Bolan, N.S., Mahimairaja, S. and Hedley, M.J. (1992) Improving the fertilizer value of poultry manures. Proceedings of the Seminar on "Eggs '92- winning in a deregulated environment", Egg Producers Federation of New Zealand, 1-15.

Culley, D.D. and Epps, E.A. (1973) Use of duckweed for waste treatment and animal feed. J.WPEF, 45, 337-347.

Kitoh, S., Shiomi, N. and Uheda, E. (1993) The growth and nitrogen fixation of Azolla filiculoides Lam. Polluted water. Aquat. Bot., 46, 129-139.

Nickell, L.G. (1961) Physiological studies with Azolla under asptic conditions. II Nutritioned studies and effects of chemicals on growth, Plyton, B.Aires, 17, 49-54.
Vermaat, J.E. and Hanif, M.K. (1998) Performance of common duckweed species (Lemnaceae) and the Waterfern Azolla filiculoides on Different Types of Waste Water.
Watanabe, I., Roger, P.A., Ladha, J.K. and Van Hove, C. (1992) Biofertilizer germplasm collections at IRRI. International Rice Research Institute, Philippines.

Research article

Indigenous Community Forest Management in Northeastern Thailand: Biodiversity Conservation through Rural Development

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Abstract Deforestation which causes the forest area decreasing and lead to the global environmental change through biodiversity loss and emissions of greenhouse gases is one of the most of important environmental problems faced by developing countries like Thailand. Forest management is the one of an important strategy in biodiversity conservation and carbon mitigation. The aim of this study was to investigate the suitable strategy for forest management in local community of Northeastern Thailand based on the community participation. Plant biodiversity in Khon Kaen local community forest 200 Rai (6.25 Rai = 1 hectare) was surveyed during 2008-2009. Focus Group Interview and SWOT analysis was used as a tool to find out the sustainable strategy for forest management. The results found that forest biodiversity was rich. Ninety-four plant species were found in this study area. Indigenous community forest management such as traditional, cultural, local commitment and believe was found to be the most suitable strategy in managing this community forest. The outcome of this project in long term would be beneficial for biodiversity conservation, carbon mitigation and sustainable rural development.

Keywords indigenous community forest management, biodiversity conservation, carbon mitigation, rural development

INTRODUCTION

Thailand has been experienced the most rapid deforestation in the last 40 years. Their forest in 1961 occupied about 27 million hectares and by 1989 has come down to 14.3 million which is only about 28% of the country. Since 1998, the forest area has been increasing up to 32.66% in 2004 (Royal Forest Department, 2004). The National Forest Policy wants the forests to be about 40% of the land area of the country. The actions taken by the government so far to remove further threat to the forests include cancellation of the contracts with the concessionaires, stoppage of green felling in the forests, some decentralization to involve the villagers in developing and protecting forests. Thailand tries to find new ways of forest management to deal with the danger of forest loss. Community forests are one solution discussed very broadly in the Thai public as well as in Thai forestry. Participation of local people in the management of forest resources seems to be a promising way to conserve remaining forest areas (Kebler, 1998).

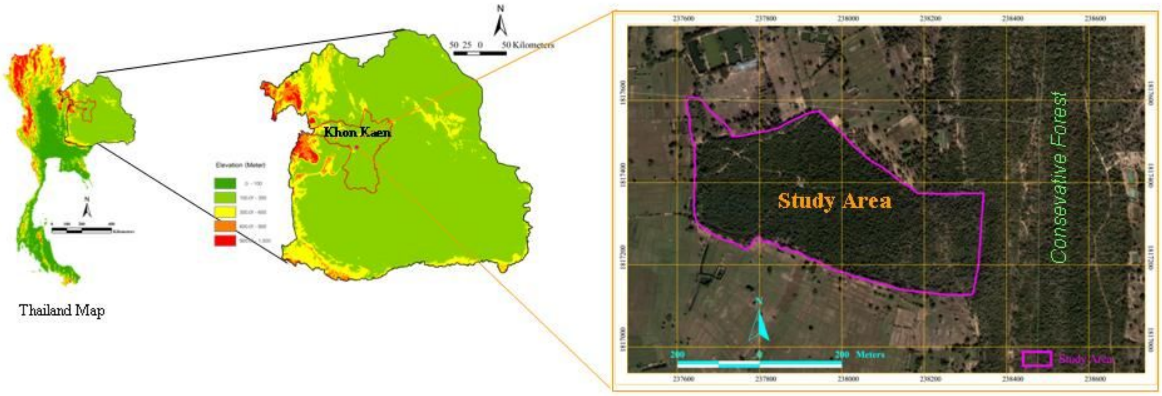
In the northeastern region of Thailand, the forest concession of 1968-1987 caused about 87% of the total regional land area in a degraded condition and has lead to new forest settlements. In 1995 to 1999, the trend of forest land in the Northeast was decreased (Office of Agricultural Economics, 2002). Causes of deforestation and forest degradation in the Northeast of Thailand include the farmers' need to improve productivity for better economic conditions leading to the expansion of agricultural land, rural poverty are including that of disadvantaged and landless people and population growth and mitigation, resulting in increased population in forest areas, etc (Kashio, 1955, Jantakad and Gilmour, 1999). About the main problem of this study area is that the Community forests and public lands have been destroyed for cultivation.

This study is thus aimed to investigate the suitable strategy for forest management in local community base on the indigenous community participation. The investigation divided in 2 parts, i.e., (1) surveying plant diversity and (2) studying attitudes of people in Yang-Kam Sub-district and the stakeholders by using focus group interview in order to motivate them to realize the important role of forest and further environmental conservation so that it would help maintain ecosystems and also reduce global warming.

MATERIALS AND METHODS

Study Area

The study area is located at zone 48Q; UTM coordinates 1817395 N and 237902 E at the part of Yang-Kam sub-district, Nong-Reu district, Khon Kaen Province, Thailand. The total of study area is covering about 200 rai and close to the conservative forest (Fig.1). But recently in this area is still of the forest area about 174 rai cause of some local people were encroached. So, the forest communities' concept was set up by the local people and TOA of Yang-Kam for intrusion prevention and forest conservation.



Cited from Google Earth (2009)

Fig. 1 Study area at Yang-Kam sub-district, Nong-reu district, Khon Kaen province, Thailand

Forest Survey

The survey was conducted along 2 main trails and surrounding of the study area covering almost 200 rai of the Yang-Kam community forest. The survey was done and worked together by the leader of forest scientist, farmer specialist on herb, local governors and villager.

Focus Group Interview and SWOT Analysis

Focus Group Interview was used including stakeholder interviews (those who reside adjacent to community forest), direct participant interviews and key person interviews. In focus group interview, information on the matters of community forest utilization and a taught of setting organization and practical administration of Yang-Kam community forest for efficiently sustainable forest resources management were requested. SWOT analysis was employed to identify the strengths, weaknesses, opportunities and threats of the community.

RESULTS

The community forest inventory indicated that, the Yang-Kam community forest is dipterocarp forest consisting of 94 plant species. Of this figure, 72 species are tree (from list No 1 to 72), 22 species are medicinal herb (from No.73 to 94). All of them are shown in Table 1.

Table 1 List of plant species were found in the study area

No.	Scientific Name	No.	Scientific Name
1	*Antidesma ghaesembilla Gaertn.*	48	*Morinda tomentosa Heyne ex Roth*
2	*Artocarpus lakoocha*	49	*Ochna integerrima Merr.*
3	*Atalantia monophylla Correa*	50	*Parinari anamense Hance*
4	*Azadirachta indica var. siamensis Valeton*	51	*Pavetta tomentosa Roxb. ex Smith*
5	*Bauhinia saccocalyx Pierre*	52	*Peltophorum dasyrachis Kurz*
6	*Beilschmiedia gammieana King ex Hook. f.*	53	*Phyllanthus emblica Linn.*
7	*Berrya mollis Wall.ex Kurz*	54	*Pterocarpus macrocarpus Kurz.*
8	*Bridelia retusa (L.) A. Juss.*	55	*Randia wittii Craib*
9	*Buchanania lanzan Spreng.*	56	*Salacia chinensis Linn.*
10	*Canarium sublatum Guill.*	57	*Schleichera oleosa (Lour.) Oken*
11	*Cansjera rheedei J.F. Gmel.*	58	*Shorea siamensis Miq.*
12	*Canthium parvifolium Roxb.*	59	*Shorea obtusa Wall.*
13	*Casearia grewiaefolia Vent.*	60	*Sindora siamensis Teijsm. ex Miq.*
14	*Cassia garrettiana Craib*	61	*Stereospermum fimbriatum (Wall. ex G.Don) A.DC.*
15	*Cordia dichotoma Forest. f.*	62	*Strychnos nux-vomica Linn.*
16	*Cratoxylum formosum Dyer*	63	*Symplocos racemosa Roxb.*
17	*Dalbergia nigrescens Kurz*	64	*Syzygium cumini (L.) Skeels*
18	*Dehaasia suborbicularis Kosterm.*	65	*Terminalia alata Heyne ex Roth*
19	*Dendrolobium triangulare Schindl.*	66	*Terminalia chebula Retz.*
20	*Dillenia obovata (Blume) Hoogland*	67	*Terminalia corticosa Pierre ex Laness.*
21	*Dioecrescis erythroclada (Kurz) Tirveng.*	68	*Urobotrya siamensis Hiepko*
22	*Diospyros coaetanea Fletch.*	69	*Vitex peduncularis Wall. ex Schauer*
23	*Diospyros ehretioides Wall.*	70	*Walsura trichostemon Miq.*
24	*Diospyros montana Roxb.*	71	*Xylia kerrii Craib & Hutch.*
25	*Dipterocarpus obtusifolius Teijsm. Ex Miq.*	72	*Zizyphus cambodiana Pierre*
26	*Dipterocarpus tuberculatus Roxb.*	73	*Acacia craibii Nielsen*
27	*Elipanthus tommentosus Kurz.*	74	*Aporosa villosa (Lindl.) Baill.*
28	*Erythrophleum teysmannii (Kurz) Craib*	75	*Asparagus racemosus willd.*
29	*Flacourtia indica Merr.*	76	*Canthium berberidifolim Geddes*
30	*Garcinia cowa Roxb.*	77	*Dillenia obovata (Blume) Hoogland*
31	*Gardenia obtusifolia Roxb.*	78	*Dioecrescis erythroclada (Kurz) Tirveng.*
32	*Gardenia sootepensis Hutch.*	79	*Dipterocarpus tuberculatus Roxb*
33	*Gomphia serrata Kanis*	80	*Dispyros ehretiioides Wall. ex G.Don*
34	*Grewia elatostemoides Coll. et Hemsl.*	81	*Elephentopus scaber L.*
35	*Heterophragma sulfureum Kurz*	82	*Enkleia siamensis Nervling*
36	*Hibiscus glanduliferus Craib*	83	*Gardenia sootepensis Hutch.*
37	*Irvingia oliveri Pierre*	84	*Gluta usitata (Wall.) Ding Hou*
38	*Lannea coroman delica (Houtt)Merr*	85	*Helicteres angustifolia L.*
39	*Litsea glutinosa (Lour.) C.B. Robinson*	86	*Hibiscus gladuliferus Craib*
40	*Lophopetalum duperreanum Pierre*	87	*Ixora cibdela Craib*
41	*Mangifera griffithii Hook.f.*	88	*Lannea coroman delica (Houtt)Merr*
42	*Melanorrhoea usitata Wall.*	89	*Maerua siamensis (Kurz) Pax.*
43	*Melientha suavis Pierre*	90	*Randia dasycarpa Bakh.f.*
44	*Memecylon scutellatum Naud*	91	*Rothmania wittii (Craib) Bremek.*
45	*Millettia leucantha Kurz*	92	*Strychnos plumosa*
46	*Mitragyna rotundifolia*	93	*Stychnos nux-vomica L.*
47	*Morinda elliptica Ridl.*	94	*Walsura villosa Wall.*

Based on the Focus Group Interview, it was found that the members of community have long been using the community forest in various forms of products, e.g., fuel wood, wood for fencing, animal ranging, non-timber products and medicinal herbs.

Besides, it was agreed among community members to formally establish Yang Kham Community Forest by the reason that it could help protecting this forest not being depleted from the present size (174 rai). The community members proposed that the organization for management should be the combination of cooperation between government sector and local community. The regulation for community forest management must be shared by people participation process and publicly inform to Yang-Kam Community.

The SWOT analysis was used to analyze the possibility of Yang-Kam community forest installation were found that the internal factor (Strengths and Weaknesses) and external factor (Opportunities and Treats), its effect to the success of the community forest setting and sustainable of community forest. SWOT analysis indicated that the local leaders, the members of Tambol Administration Organization (TAO) are rather strong to foster their community forest, but the weaknesses are that of lacking of knowledge base and understanding in sustainable forest management. Furthermore, focus group members were mutually agreed that the opportunity to sustainably and continuously utilize this community forest is by the cooperation of related government sectors. This is due to the threats stemmed from intrusion of those people residing around this community forest gradually.

DISCUSSIONS AND CONCLUSIONS

Forest biodiversity in Yang Kham Community Forest was rich. Ninety-four plant species were found in this study area. There were 72 species of tree and 22 species of herb. Most of the tree there were 10-15 years old. The original forest area was around 200 rai but now only 174 rai. If there is no activity on the forest management, deforestation would occur. From the focus group interviews, indigenous community forest management such as traditional, cultural, local commitment and belief was found to be the most suitable strategy in managing this community forest. This strategy is called the applied forest management. The outcome of this project in long term would be beneficial for biodiversity conservation, carbon mitigation and sustainable rural development which the same study was found with the case study of community forest management in Mexico (Klooster and Masera, 2000). In Thailand, the knowledge and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity should be respected. There is interest in learning more about traditional ecological knowledge and how it can be integrated into forest biodiversity conservation.

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REFERENCES

David O'Connor (2008) Governing the global commons: Linking carbon sequestration and biodiversity conservation in tropical forests. Global Environmental Change, 18, 368-374.

Jantakad, P. and Gilmour (1999) Forest rehabilitation policy and practice in Thailand. 33 (mimeograph)

Kanok Rerkasem, Narit Yimyam and Benjavan Rerkasem (2009) Land use transformation in the mountainous mainland Southeast Asia region and the role of indigenous knowledge and skills in forest management.

Forest Ecology and Management, 257, 2035-2043.
Kashio, M. (1995) Sustainable forest management in Asia and the Pasific. Proceedings of a Regional Expert Consortium on Implementing Sustainable Forest Management in Asia and the Pacific, FAO, 17-31.
Klooster, D.and Masera, O. (2000) Community forest management in Mexico: Carbon mitigation and biodiversity conservation through rural development. Global Environmental Change, 10, 259-272.
Preet Pal Singh (2008) Exploring biodiversity and climate change benefits of community-based forest management. Global Environmental Change, 18, 468-478.
Royal Forest Department (2004) Forestry statistics of Thailand. Bangkok Information Office. Bangkok, Thailand.
Susan Charnley, Fischer, A.P. and Jones, E.T. (2007) Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest. Forest Ecology and Management, 246, 14-28.

Research article

The Influence of Eucalyptus Plantation on the Soil Ecosystem under Different Soil Series in Northeast Thailand

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Abstract Eucalyptus has been introduced to the farmer and extensively grown in Thailand for paper pulp production and giving high income to the farmer. However, the long term impact of eucalyptus plantation on soil ecosystem has been less studied. Therefore, the aim of this study was to investigate the influence of eucalyptus plantation on the soil ecosystem under different soil series in Northeast Thailand. The study site was located at Amphur Nam Pong, Khon Kaen, Northeast of Thailand. The biological, physical and chemical soil properties in Eucalyptus plantation (more than 3 years) were analyzed compared with the dry dipterocarp forest nearby. Moreover, impacts of eucalyptus on soil biota (Earthworm) under different soil series (Pimai and Nampong soil series) were evaluated in the laboratory. The results indicated that microbial activity such as soil respiration, microbial biomass nitrogen and microbial biomass carbon in Eucalyptus plantation were less than in the dry dipterocarp forest significantly from 3.950 to 5.916 mg C/day for microbial activity and 15.811 and 108.620 µg N/g soil for microbial biomass nitrogen and 102.24 to 244.25 µg C/g for soil microbial biomass carbon ($p<0.01$), respectively. For the 50% avoidance of the earthworm to eucalyptus leave in Pimai (Pm) and Nampong (Ng) soil series were 17.35 and 19.44 g/kg soil, respectively. The result showed that eucalyptus plantation has adverse effect on soil microbial activity in soil ecosystem and differ in each soil series. The result of this study is useful as decision making in appropriate land use management. The impact of eucalyptus plantation should be considering of site specific location and find out the suitable place to grow eucalyptus.

Keywords eucalyptus, soil characteristics, soil ecosystem

INTRODUCTION

Eucalyptus has been introduced to the farmer and extensively grown in Thailand for paper pulp production and giving high income to the farmer. Eucalyptus plantation area has been increasing. In 2007, eucalyptus plantation was 20 million rai (1 ha = 6.25 rai) (Department of Agriculture, 2009) and showed the trend of increasing in next year. Now eucalyptus plantation has been extended into northeast area in Thailand due to the suitable condition making eucalyptus tree grow faster than other parts of Thailand (The Thailand Research Fund, 2006). However, the long term impact on soil ecosystem has been less studied. One study of the impact of eucalyptus on soil biota was done in the earthworm *Pontoscolex corethrurus.* The result found that the earthworm population in eucalyptus plantation less than in albizia plantation. Mean earthworm densities ranged from 92 earthworms per m^2 in eucalyptus plantation area and 469 earthworms per m^2 for albizia plantation area (Zou, 1993). The study of the impact of eucalyptus on ecosystem mostly has been done on the water use and plant germination. Therefore, the influence of eucalyptus plantation on the soil ecosystem under different soil series in Northeast Thailand was investigated. The result of this study will be useful for involved organizations for decision making and land use management. The impact of eucalyptus plantation should be considering of site specific location and find out the suitable place to grow eucalyptus.

MATERIAL AND METHODS

The study of the influence of eucalyptus plantation on the soil ecosystem under different soil series in Northeast Thailand was done in laboratory experiment and field study. The study site was located at Amphur Nam Pong, Khon Kaen, Northeast of Thailand (Global Position System location is E 16^0, $47^'$, $5.77^{''}$, N 102^0, $46^'$, $11.28^{''}$).

Laboratory experiment

The impacts of eucalyptus on soil biota (Earthworm) under different soil series (Pimai and Nampong soil series) were evaluated in the laboratory to study on the avoidance of earthworm. A laboratory experiment was set up to find percent (%) avoidance of earthworm on eucalyptus leave *(Eucalyptus camaldulensis)* in the two different soil series. For each treatment, 200 g of soil was add in two side of plastic box (7cm x 11cm x 5cm). One side containing soil without the eucalyptus leave and other side containing soil with eucalyptus leave (60 mesh size) (Chander, 1995) in different concentrations in each treatment (Treatment 1: Soil plus eucalyptus leaves at 10 g/kg soil, Treatment 2: Soil plus eucalyptus leaves at 20 g/kg soil, and Treatment 3: Soil plus eucalyptus leaves at 40 g/kg soil). After that the earthworm *Eudrillus eugeniae* were added in center plastic box and left it for 24 hours to monitor the proportion of earthworm in each side and then calculation for the percent of avoidance (%) as followed.

$$PA = \frac{NECS - NETS}{TN} x100 \qquad (1)$$

Where: PA : The percent of avoidance (%)
NECS : Number of earthworm in control side
NETS : Number of earthworm in treatment side
TN : Total number of earthworm in each treatment

Field studies

The biological, physical and chemical soil properties in Eucalyptus plantation were analyzed comparing with the dry dipterocarp forest nearby. Soil samples were collected at the various distances from the eucalyptus plantation and dry dipterocarp forest and analyzed for microbial biomass C, microbial biomass N and soil microbial activity.

Soil microbial biomass measurement

Microbial biomass C was measured by the chloroform fumigation extraction method (Sparling, 1991; Tate et al. 1988). Two replications of 10 g of each soil were fumigated with ethanol-free chloroform for 24 hour. After that soil were extracted with 0.5 M K_2SO_4 (using a soil: solution ratio of 1:5) for 30 minute. Two replication of each unfumigated soil were extracts similarly at time fumigation commenced and filtered soil extracts stored at -15 ^oC until analysis.

Microbial biomass N was measured by the chloroform fumigation extraction method (Sparling, 1991; Tate et al. 1988). Two replications of 10 g portions of each soil were fumigation with ethanol-free chloroform for 24 hour. After extracted with 1M KCl (using a soil: solution ration of 1:5) for 30 minute, the soils were measured by spectrophotometer at 570 nm. Microbial biomass C and Microbial biomass N were calculated from:

MBC, MBN= (Microbial biomass C, Microbial biomass N chloroform fumigation) – (Microbial biomass C, Microbial biomass N unfumigared).

Soil microbial activity

Soil microbial activity was measured for soil respiration by the method of Anderson (1992) and Rowell (1997). As many as 15 ml of NaOH was added in small vial (5 cm high and 2.5 cm diameter) and hang in the jar containing soil and leave for 24 hour. Excess NaOH was titrated with 0.05 N HCl by adding 2.5 M $BaCl_2$. Soil respiration was calculated from:

$$SR = (B - V) N \, x \, 6 \quad (2)$$

Where SR : Soil respiration (mg Carbon unit)
B : HCl for titration blank (ml)
V : HCl for titration sample (ml)
N : Concentrated HCl

RUSULTS

The results indicated that microbial activity such as soil respiration, microbial biomass nitrogen and microbial biomass carbon in Eucalyptus plantation were significantly less than in the dry dipterocarp forest from 3.950 to 5.916 mg C/day for microbial activity and 15.811 and 108.620 µg N/g soil for microbial biomass nitrogen and 102.24 to 244.25 µg C/g for soil microbial biomass carbon ($p<0.01$), respectively (Table 1). For the 50% avoidance of the earthworm to eucalyptus leave in Pimai (Pm) and Nampong (Ng) soil series were 17.35 and 19.44 g/kg soil, respectively (Fig.1). The soil chemical and physical properties in Eucalyptus plantation compared with the dry dipterocarp forest showed in Table 2 and 3. The soil chemical and physical properties in Eucalyptus plantation compared with the dry dipterocarp forest. The result found that organic matter (OM), total N, Available P (ppm) and Extractable K (ppm) in eucalyptus plantation less than in the forest. The better soil physical property was found in the forest than eucalyptus plantation.

Table 1 Microbial biomass N (µg N/g soil) and microbial biomass C (µg C/g soil) and soil microbial activity (mg) in Eucalyptus plantation and dry dipterocarp forest

Area	Microbial biomass N (µg N/g soil)	Microbial biomass C (µg C/g soil)	Soil microbial activity (mg)
Eucalyptus	15.81 b	102.24 b	3.950 b
Dry dipterocarp forest	108.62 a	244.25 a	5.917 a

a,b Significant at $P \leq 0.05$ Values followed by the same letter in the same column

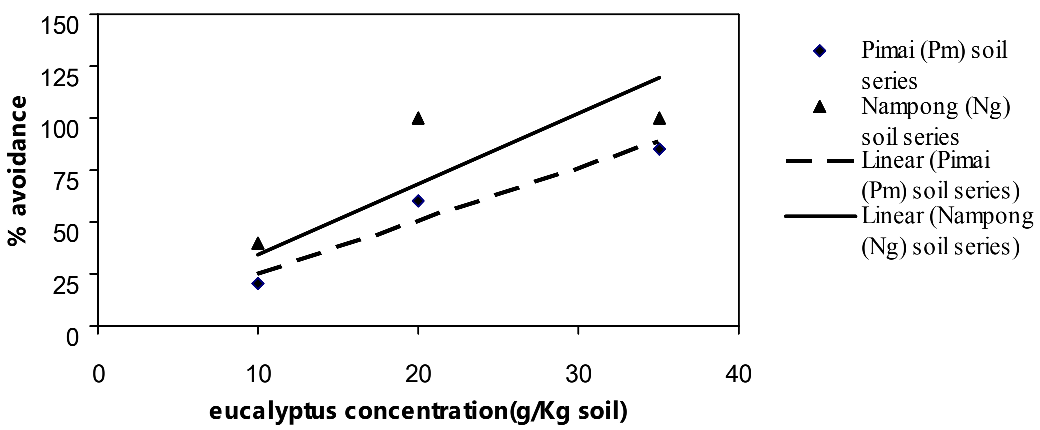

Fig. 1 Percent (%) in avoidance of earthworm exposure to the different eucalyptus concentration in Pimai (Pm) and Nampong (Ng) soil series

Table 2 Chemical soil properties in Eucalyptus plantation and dry dipterocarp forest

Area	Dry dipterocarp forest	Eucalyptus
pH (1:1)	5.05±0.04	4.87±0.44
% OM	1.71±1.07	0.67±0.04
%T-N	0.02±0.10	0.03±0.00
Available P (ppm)	3.66±1.76	2.05±0.24
Extractable K (ppm)	61.67±41.93	50.67±2.52

Values are mean ± standard deviation. Mean with the same letter in the row are not significantly different control (P>0.05).

Table 3 Physical soil properties in Eucalyptus plantation and dry dipterocarp forest

Area	Dry dipterocarp forest	Eucalyptus
Bulk density (g/cm^3)	1.40±0.19	1.58±0.05
Saturated hydraulic conductivity (cm/h)	0.33±0.29	1.16±0.54
Soil moisture (%)	20.61±4.75	12.81±6.30

Values are mean ± standard deviation. Mean with the same letter in the row are not significantly different from control (P>0.05).

CONCLUSION

According to the results, it indicated that eucalyptus plantation has some adverse effect on soil microbial activity in soil ecosystem and differ in each soil series. However, organic matter decomposition is a complex process, which involves leaching, physical abrasion, microbial conditioning and processing by soil biota. The relative importance of these factors can be changed, resulting in highly variable species-and site-specific dynamics (Pozo et al., 1998). The result of this study will be useful for involved organizations for decision making and land use management. The impact of eucalyptus plantation should be considering of site specific location and find out the suitable place for eucalyptus plantation.

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REFERENCES

Anderson, T.R. (1992) Modelling the influence of food C:N ratio, and respiration on growth and nitrogen excretion in marine zooplankton and bacteria. Journal of Plankton Research, 14, 1645-1671.

Chander, K., Goyal, S. and Kapoor, K.K. (1995) Microbial biomass dynamics during the decomposition of leaf litter of poplar and eucalyptus in a sandy loam. Bio Fertil Soils, 19, 357-362.

Department of Agriculture (2009) retrieved August 5, 2009 from http://it.doa.go.th/pibai/pibai/n11/v_11mar/ceaksong.htm.

Pozo, J., Basaguren, A., El´osegui, A., Molinero, J., Fabre, E. and Chauvet, E. (1998) Afforestation with Eucalyptus globulus and leaf litter decomposition in streams of northern Spain. Hydrobiologia 373/374, 101-109.

Rowell, D.L. (1997) Soil Science: methods and application. John Wiley and Sons, Inc. New York, USA, 117-121.

Sparling, G.P. (1991) Organic matter C and microbial biomass C as indicators of sustainable land use. Proceeding of the International workshop on evaluation for sustainable land management in developing world, IBCRAM proceeding, No. 12.

Tate, K.R., Ross, D.J., and Feltham, C.W. (1988) A direct extraction method to estimate soil microbial C, Effect of experiment variables and some different calibration procedures. Soil Biol. Biochem, 20, 329-335.

The Thailand Research Fund (2006) http://www.trf.or.th/News/Content.asp?Art_ID=574.

Zou Xiaoming (1993) Species effects on earthworm density in tropical tree plantation in Hawaii. Bio Fertil Soils, 15, 35-38.

Research article

Vermicompost: Tool for Agro-industrial Waste Management and Sustainable Agriculture

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Abstract Rapid increasing of agro-industrial waste production has caused a serious environmental damage in Thailand. Thus, a proper management of agro-industrial waste has become an important issue. The objective of this study was to prove vermicompost as a suitable tool for agro-industrial waste management. The experiment of feasibility study of using vermicompost to reduce the cadmium contaminated in some typical Thai soil (Nampong (Sandy) and Phimai (Clay) soil series) were conducted by spike soil at various concentrations of Cd (0, 5, 50 mg/kg of Cd) as $CdCl_2$. The physical and chemical properties of soil were analyzed before and after compost and vermicompost. The results indicated that vermicompost could absorb the cadmium in sludge waste and subsequently reduce the cadmium contamination. Earthworm activity significantly increased the availability of soil pH, P, K, Na, Mg, Ca and decreased organic carbon as well as Cd contamination in soil. The production of earthworm was increased followed by the increasing of agro industrial waste. Thus vermicompost is a promising method for agro-industrial waste management that use locally available materials, enrich microorganism in soil and less impact on the environment.

Keywords vermicompost, agro-industrial waste, sustainable agriculture

INTRODUCTION

The increasing rate of agro-industrial waste due to the large scale of urbanization and a consequence of economic development has become a problem that produces the huge quantities of waste in Thailand and causes a serious environmental problem which is difficult for management. Among the available alternatives for disposing of sewage waste sludge, one of the most convenient ways is using the waste in agriculture purpose. Agro-industrial waste is one of the problems and difficult to manage as Thailand is an agricultural country. The increasing rate at which organic waste are generated has become a problem for disposal and/or management. Currently, the management and disposal of agro-industrial waste production is one of the most critical environmental issues. Therefore, the study related on the safe reuse and management of agro-industrial waste is important. According to Appelhof (1981), the appropriate disposal of waste should involve both maximum cost effective recovery of recyclable constituents and transformation of non-recoverable material into forms, which do not present environmental hazards.

Vermicomposting is the earthworm activity that turn the organic waste into the fertilizer. The process of vermicompost is broken down organic residues by earthworms and microorganisms (Aira and Dominguez, 2008). The stabilization process of organic waste materials involves the joint action between earthworms and microorganisms. Although microbes are responsible for biochemical degradation of organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering the biological activity (Suthar, 2007). Pimm (1982) reported that the dynamics of decomposition systems of vermicompost depend on the inputs of resources. There is a need of safe technology of disposal agro-industrial waste; the technologies must be ecologically sound, economically viable and socially acceptable. Therefore, vermicompost technologies fulfill all the conditions for suitable waste management. It is one of the common ways to decrease sludge volume. Cadmium is one of the main risk metals in soil and waste sludge (Alloway, 1995). Vermicompost may be used to assess the impact of cadmium contaminated soil and waste sludge on physiological state, reproduction and development of the animals and also reduce the cadmium residues in sludge and soil. The objective of this study was to determine the effect of earthworm (*Eudrillus eugeniae*) activity on suitable tool for Agro-industrial waste management and source of nutrients for plant production in sustainable agriculture.

MATERIALS AND METHODS

The earthworms (*Eudrillus eugeniae*) were collected from the meadow, which had no history of input of heavy metals. They were carefully brought to the laboratory along with the moist soil and culture in laboratory and acclimatized for 1 month under laboratory conditions in polyethylene buckets (culture pot) containing soil. Citric acid waste from ago-industrial waste was collected from Samutsakorn Province, Thailand. The citric acid waste was dried in direct sunlight for 1 month and passed through 2 mm of sieve. The chemical characteristics of citric acid waste are reported with its moisture to 50%. Cow manure was used as amendment material. The fresh cow manure used in this experiment was obtained from a local cow house. The investigation was carried out in a laboratory at the Faculty of Agriculture, Khon Kaen University, Thailand. The experimental units were conducted in polyethylene culture pots, which have four liters capacity of each. Nampong (Sandy) and Phimai (Clay) soil series were used in this experiment. Air-dried soil and farmyard manure were mixed in the ratio of 9:1 for the experiments. These mixtures at 400g were taken in each experimental pot to provide initial favorable environmental conditions for the worms.

The experiment was laid out in completely randomized design (CRD) with 3 replications. Two treatments were used: (i) vermicompost (soil + citric acid waste + cow manure + metal + earthworm), (ii) compost (soil + citric acid waste + cow manure + metal). To measure the normal activity of earthworms (*Eudrillus eugeniae*) in the prepared soil, 0, 5, 50 mg/kg of $CdCl_2$ were applied to each experimental beds containing ten earthworms. The moisture content was adjusted to 50% of WHC (Water Holding Capacity). The pH of soil was 6.08±0.08. Temperature was maintained at 30±2 $^{\circ}$C. The day of releasing the earthworms was marked at 0, 15, 30, 60 days.

Chemical analysis in soil and earthworm tissue samples

The pH was measured using digital pH meter in 1/ 2.5 (w/v) by deionizered water. Organic carbon was determined by the partially-oxidation method (Walkley and Black, 1934). Total N (Total nitrogen) was measured by micro Kjeldahl method (Jackson, 1973; Bremner and Mlvaney, 1982). Extractable phosphorous was determined by following BrayII extraction method (Schroth et.al, 2003) by spectrophotometer. Exchangeable elements (K, Ca and Mg) were determined after extracting the sample using ammonium acetate extractable method (Simard, 1993); analyzed by flame atomic absorption spectrophotometer (FAAS). C:N ratio was calculated from the measured value of C and N. To measure cadmium and total cadmium in soil and earthworm tissue; DTPA-Cd was determined after extracting using DTPA solution by analysis flame atomic absorption spectrophotometer (FAAS). To determine total metal concentrations, soil and earthworm tissue samples were digested by acid mixture 1:2 (HNO_3–$HClO_4$) (Tessier et al., 1979; Sparks, et al., 1996;; Maity et al., 2008; Suthar and Singh, 2008). 1 g dry sample was heated with 10 ml concentrated HNO_3–$HClO_4$ at 170°C for 3-4 hour; and analyzed by flame atomic absorption spectrophotometer (FAAS).

Statistical analysis

All results were analysed the means of three replicates. One-way ANOVA was used to analyze the significant difference between treatments and Turkey HSD test was used to compare the means by using Statistix 8.0 and Microsoft Excel.

RESULTS AND DISCUSSION

The pH values of the Nampong Soil (Ng) and Phimai Soil (Pm) on 0, 15, 30 and 60 days for the different concentrations of Cd treatments are represented in Table 1. The result clearly showed that there was significant difference in pH value among the treatments. However, Phimai soil has been found to have significantly higher soil pH in all cadmium treated vermicompost after 60 days. The comparison of two soil series (Nampong and Phimai soil series) indicated that there was no significant difference on pH values. The increasing pH were found in every treatments because of the ability of earthworm in releasing calcium compound and producing alkaline urine into the environments (Hu et al., 1998; Salmon, 2001) by calciferous glands. The pH of vermicompost beds may also be increased by the high activity of gut enzyme alkaline phosphates (Pramanik et al., 2007).

Table 1 pH value of Nampong soil and Phimai soil between vermicompost (VCP) and without earthworm (Compost: CP)

Time	Nampong Soil (Ng)				Phimai Soil (Pm)			
	5 mg/kg		50 mg/kg		5 mg/kg		50 mg/kg	
	CP	VCP	CP	VCP	CP	VCP	CP	VCP
0	6.06±0.01	6.06±0.01	6.13±0.01	6.13±0.01	5.57±0.02	5.57±0.02	5.75±0.05	5.75±0.05
15	7.06±0.01	7.26±0.01	7.13±0.01	7.03±0.01	6.57±0.02	6.76±0.01	6.75±0.05	6.53±0.06
30	7.22±0.03	7.42±0.03	7.3±0.05	7.16±0.05	7.36±0.01	7.31±0.02	7.18±0.03	7.22±0.03
60	7.16±0.02	7.55±0.05	7.25±0.02	7.42±0.03	7.26±0.01	7.87±0.06	7.15±0.02	7.88±0.04

In Namphong soil treatment, soil characteristic changes in the earthworm compost (Vermicompost) and without earthworm (Compost) found that after fermentation and maturing in 30 days, the organic carbon and C:N ratio were lower in both vermicompost and compost. The organic carbon and C:N ratio reduction was recorded that the ranges of the organic carbon were CP0,50 and VCP0,50 of 62-63% and 60-64%, respectively and the ranges of C:N ratio were 66-81% and 78-87%. The total nitrogen, exchangeable K, Ca, Mg and available P showed a significant ($P < 0.05$) increasing the percentage of different between VCP and CP that CP0 = 11.1, -26.2, 12.6, 23.1, 27% and CP50 = 0.6, 27.9, 53.3, 6.3,-2.7%, respectively. As the percentage of different after fermentation and maturing in 30 days in VCP0= 68.5, 58.7, 66.9, 55.9, 93.4 % and VCP50= 39.4, 78.3, 62.5, 69.0, 45.1, 93.2 % were recorded (Table 2).

In Phimai soil treatment, soil characteristic changes in the soil earthworm compost and without earthworm found that after fermentation and maturing in 30 days the organic carbon and C:N ratio values were lower in vermicompost of than the compost material and a reduction was recorded every cadmium concentration. Organic carbon and C:N ratio values were showed significantly ($P < 0.05$) decrease the ranges of CP0 were 15.2% and 19.6%, CP50 were 21.7% and 34.4% when compare with earthworm compost (Vermicompost) as VCP0 were 38.8% and 75.4%, VCP50 were 40.8% and 61.0%. The total nitrogen, exchangeable K, Ca, Mg and available P showed significantly ($P < 0.05$) increase the percentage of different of between VCP and CP that CP0 = 5.4, 2.3, 12.1, 29.1, -135.8% and CP50 = 16.7, 40.8, 51.6, 43.3, 15.9 %, respectively. As the percentage of different after fermentation and maturing in 30 days in VCP0= 60.1, 54.7, 68.9, 14.0, 86.3% and VCP50= 34.6, 24.6, 43.1, 9.6, 82.8 % were also observed (Table 2).

Cadmium mitigation in soil

The results showed that the DTPA-Cd concentration in Nampong and Phimai soil after 60 days was decreased for each treatment beds (Fig. 1). The comparison between Vermicompost and Compost showed a significant DTPA-Cd decreasing trend ($P < 0.05$). In addition, waste treatment through vermicompost provided better cadmium absorptions as compared to the waste treatment without earthworm (Compost). This may be due to the absorption of cadmium in sludge waste and earthworm tissue which help to manage reduction cadmium in soil and decreased toxic cadmium to plant and micro organism (Suthar, 2008).

Table 2 Organic carbon (OC %), total nitrogen (TN), C:N ratio, exchangeable K, Ca and Mg and available phosphorous between vermicompost (VCP) and without earthworm (Compost: CP)

Parameter	Time	Nampong soil (Ng)				Phimai soil (Pm)			
		0 mg/kg		50 mg/kg		0 mg/kg		50 mg/kg	
		CP	VCP	CP	VCP	VCP	CP	CP	VCP
%OC	0d	3.12±0.01	3.12±0.01	3.1±0.0	3.1±0.0	2.76±0.01	2.76±0.01	3.36±0.02	3.36±0.02
	30d	1.17±0.06	1.23±0.03	1.12±0.05	1.1±0.11	2.34±0.09	1.69±0.01	2.63±0.04	1.99±0.08
Total N	0d	0.056±0.01	0.056±0.01	0.083±0.0	0.083±0.0	0.122±0.003	0.122±0.003	0.125±0.007	0.125±0.07
	30d	0.063±0.002	0.178±0.02	0.087±0.01	0.137±0.02	0.129±0.02	0.306±0.03	0.15±0.02	0.191±0.01
C:N ratio	0d	55.36±0.03	55.36±0.40	31.98±1.60	37.64±1.20	22.6±0.07	22.6±0.50	26.9±1.60	26.9±0.60
	30d	18.74±1.20	6.97±1.20	5.99±0.90	8.15±1.50	18.18±0.23	5.56±0.23	17.64±2.81	10.48±2.81
Exch.K	0d	640±10.0	640±10.0	665±28.0	665±28.0	850±10.0	850±10.0	942±37.0	942±37.0
	30d	507±16.0	1,550±10.0	922±11.0	1,775±34.0	870±10.0	1,875±41.0	1,592±19.0	1,250±23.0
Exch.Ca	0d	1,640±10.0	1,640±10.0	1,476±47.0	1,476±47.0	2,166±5.0	2,166±5.0	2,702±53.0	2,702±53.0
	30d	1,877±23.0	4,950±45.0	3,158±28.0	4,760±43.0	2,463±15.0	6,975±35.0	5,578±12.0	4,750±35.0
Exch.Mg	0d	50±1.0	60±1.0	74±3.0	84±3.0	244±2.0	344±2.0	267±4.0	367±5.0
	30d	65±4.0	136±5.0	79±1.0	153±3.0	344±5.0	400±6.0	472±12.0	406±11.0
Avail.P	0d	72±2.0	72±2.0	77±2.0	77±2.0	158±1.0	158±1.0	190±5.0	190±5.0
	30d	27±1.0	1,085±12.0	75±2.0	1,135±34.0	67±4.0	1,154±59.0	226±4.0	1,104±29.0

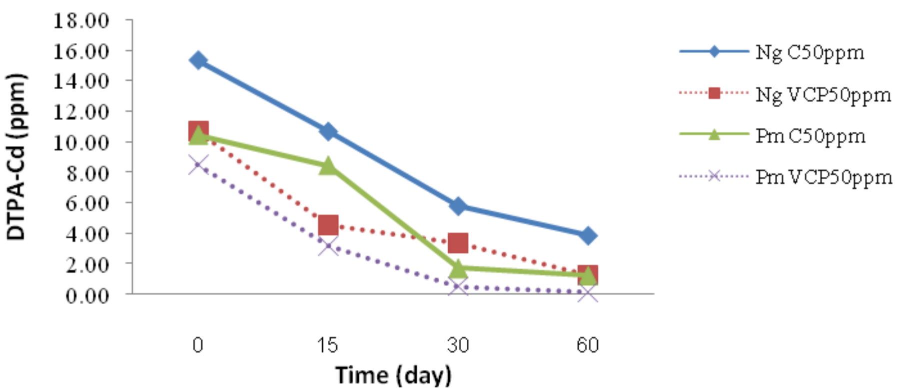

Fig. 1 DTPA-Cd in Nampong soil and Phimai between vermicompost (VCP) and without earthworm (Compost: CP)

Cadmium in earthworm tissue

The results showed that cadmium concentration in earthworm tissue after 60 days increased significantly with the increasing of cadmium concentration in earthworm ($P<0.05$) (Fig. 2). Thus, increasing of cadmium in earthworm tissue helped to reduce cadmium concentration in soil than without earthworm (Compost). The difference for tissues metal contents could be related to the feeding or feeding rate or/and amount of metals in ingesting materials by inoculated earthworms. Some earlier studies have revealed that earthworm can accumulate a considerable amount of metals in their tissues if reared for long periods in contaminated soil/substrates (Lukkari et al., 2006; Suthar, 2008; Suthar and Singh, 2008).

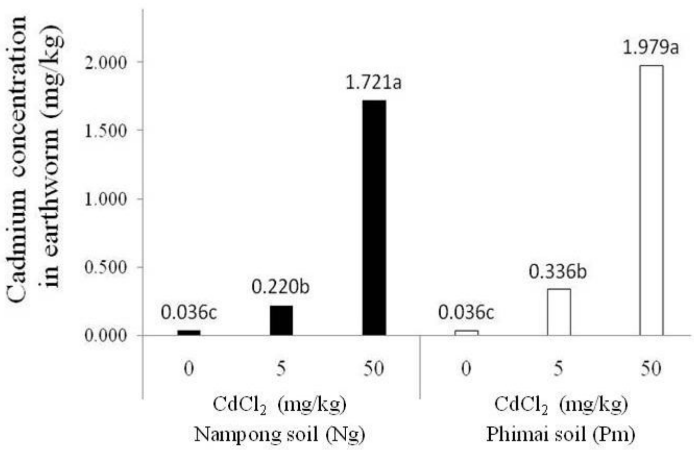

Fig. 2 Cadmium concentration in earthworm tissue

The results showed that vermicomposting of citric acid waste and cow manure were loss of organic carbon and C:N ratio. That means vermicomposting help to reduce organic waste and turn on the useful fertilizer. During the vermicomposting process, inoculated earthworms maintain aerobic condition in the wastes, convert a portion of the organic material into worm biomass and respiration products and expel the remaining partially stabilized product (vermicompost) (Suthar and Singh, 2008). Lee, (1992) and Le Bayon and Binet, (2006) suggested that the passage of organic matter through the gut of earthworm is converted to available P forms, which are more available to plants. Some previous studies also indicated the increasing of potassium content in vermicompost by the end of the experiment (Manna, et al., 2003; Suthar, 2007). The results obtained in this study demonstrated higher potassium concentration of the end product prepared from sewage sludge. The C:N ratio of the substrate material reflects the organic waste mineralization and stabilization during the process of composting or vermicomposting.

CONCLUSIONS

Agro-industrial waste (citric acid waste sludge and cow manure) has great agronomic and economic potentials as well as sustaining the environment. This study suggests that bio-stabilization of agro-industrial waste sludge using earthworm could be a potential technology to convert noxious agro-industrial and heavy metal in soil by-product into nutrient rich bio-fertilizer. The vermicomposting process showed a demonstrable impact on cadmium metal concentration of soil. The higher values of bio-concentration factors (BCFs) for different cadmium metals indicate that earthworm can accumulate a considerable amount of metals in their tissues. Earthworm biomass production and reproduction performance was excellent in bedding those contained lower proportions of agro-industrial waste sludge e.g., vermicompost which suggests that industrial sludge can retard the potentials of composting earthworms if applied at higher rate in vermibeds. Finally, agro industrial waste could be utilized as an efficient soil conditioner for sustainable land practices after processing by composting earthworms.

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REFERENCES

Aira, M. and Dominguez, J. (2008) Optimizing vermicomposting of animal wastes: Effects of rate of manure application on carbon loss and microbial stabilization. Journal of Environmental Management, 88, 1525-1529.

Alloway, B.J. (1995) Cadmium. In B.J. Alloway (Ed.), Heavy metals in soils, Blakie Academic and Professional, An Imprint of Chapman and Hall, Glasgow, UK, 122-151.

Appelhof, M. (1981) Workshop on the role of earthworm in the stabilization of organic residues. Vol. I, Proceedings, Beech Leaf Press, Michigan, USA, 315.

Bremner, J.M. and Mulvaney, C.S. (1982) Total nitrogen. Methods of soil analysis, Part 2. Agronomy monograph 9. American Society of Agronomy, WI, USA, 595-624.

Hu, F., Wu, X.Q., Li, H.X. and Wu, S.M. (1998) Effects of earthworm and ants on the properties of red soils (in Chinese). In: Research on the red soil ecosystem. China Agricultural Science and Technology Publishing House, Beijing, China, 276-285.

Jackson, M.L. (1973) Soil chemical analysis. Pranctice Hall of India, New Delhi, India.

Le Bayon, R.C. and Binet, F. (2006) Earthworm changes the distribution and availability of phosphorous in organic substrates. Soil Biol. Biochem., 38, 235-246.

Lee, K.E. (1992) Some trends opportunities in earthworm research or: Darwin's children, The future of our discipline. Soil Biol. Biochem., 24, 1765-1771.

Lukkari, T., Teno, S., Vaisanen, A. and Haimi, J. (2006) Effect of earthworms on decomposition and metal availability in contaminated soil: Microcosm studies of populations with different exposure histories. Soil Biol Biochem, 38, 359-70.

Maity, S., Roy, S., Chaudhury, S. and Bhattacharya, S. (2008) Antioxidant responses of the earthworm Lampito mauritii exposed to Pb and Zn contaminated soil. Environ. Pollut., 151, 1-7.

Manna, M.C., Jha, S., Ghosh, P.K. and Acharya, C.L. (2003) Comparative efficiency of three epigeic earthworms under different deciduous forest litters decomposition. Bioresource Tech., 88 (3), 197-206.

Pimm, S.L. (1982) Food Webs. Chapman and Hall, London, UK.

Pramanik, P., Ghosh, G.K., Ghosal, P.K. and Banik, P. (2007) Changes in organic-C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants. Bioresour. Technol., 98, 2485-2494.

Salmon, S. (2001) Earthworm excreta (mucus and urine) affect the distribution of springtails in forest soils. Biol. Fert. Soils, 34, 304-310.

Schroth, G., Lehmann, J. and Barrios, E. (2003) Soil nutrient availability and acidity. CABI Pub., Wallingford. 93-190.

Simard, R.R. (1993) Ammonium acetate extractable elements. In R. Martin and S. Carter (Eds), Soil sampling and methods of analysis. Lewis Publisher, Florida, USA.

Sparks, D.L., Oage, A.L., Helmke, P.A., Loeppert, R.M., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T. and Sumner, M.E. (1996) Chemical methods. (Methods of soil analysis, part 3). Soil Sci.Soc. Am. J., 1390, 39-43.

Suthar, S. (2007) Vermicomposting potential of Perionyx sansibaricus (Perrier) in different waste materials. Bioresource Tech., 98, 1231-1237.

Suthar, S. (2008) Development of a novel epigeic-anecic-based polyculture vermireactor for efficient treatment of municipal sewage water sludge. Int J Environ Waste Manage, 2(1/2), 84-101.

Suthar, S. and Singh, S. (2008) Feasibility of vermicomposting in biostabilization of sludge from a distillery industry. Science of the total environment, 394, 237-243.

Tessier, A., Campbell, P.G.C. and Bisson, M. (1979) Sequential extraction procedure for the speciation of particculate trace metals. Analytical Chemistry, 51, No 7.

Walkley, A. and Black, I.A. (1934) An examination of the Degtareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci., 34, 29-38.

Research article

Effects of Stubble Mulching on Plant Growth of Pearl Millet and Soil Moisture Condition

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Abstract Sub-Saharan Africa is one of the most vulnerable regions, as desertification has been advancing. In order to mitigate the degradation of crop productivity, this study aims to investigate how to apply pearl millet stalk residues for improving soil moisture condition and plant growth. The experiment was carried out at a greenhouse of Tokyo University of Agriculture, Japan. Pearl millet (*Pennisetum glaucum* (L.) R. Br.) was cultivated at each plot of 6.5 m long and 0.8 m wide, and soil moisture was monitored with a TDR soil moisture meter. Nine plots were divided into 3 groups based on irrigation intensity; the first was irrigated at 3 to 6 mm/day as standard plots, the second at 2/3 of the standard as slightly water-saving plots and the third at 1/3 of the standard as water-saving plots. Each group was constituted with 3 different treatments; stubble mulching with pearl millet stalk residues, mixing soil with pearl millet stalk residues and non-treatment as control. The results from non-treatment indicated that plant growth of pearl millet above ground surface did not show a significant difference among the plots under the different irrigation intensities. Under non-treatment condition, pearl millet even in the 2/3 and 1/3 water-saving plots grew as well as that in the standard plots. However, the fresh weights of non-treatment were significantly lower than that of other treatments, stubble mulching or mixing soil with pearl millet stalk residues, at 95% confidence level. Additionally, there was a tendency for pearl millet growth of stubble mulching to be higher than that of mixing soil with pearl millet stalk residues. This implies that mulching with pearl millet stalk residues can be more effective for plant growth. The utilization of stubble mulching in the production of crops under low rainfall condition such as Sub-Saharan Africa is expected to play beneficial roles such as improving soil moisture condition and plant growth.

Keywords stubble mulching, soil moisture, pearl millet, Sub-Saharan Africa

INTRODUCTION

Sub-Saharan Africa (hereinafter, SSA) is increasing the annual percentage rate of population at 2.3% (UNFPA, 2008). SSA is one of the most hazardous regions as desertification has been advancing severely, and higher than 35% of total population is undernourishment at 16 countries (WFP, 2009). Especially, the amounts of annual precipitation in West African countries bounding the Sahara in SSA are less than 500 mm (FAO, 2000), in addition to the insufficient nutrient of soil. Therefore, it is difficult to irrigate sufficiently for crop production with limited water resources.

However, it is a global issue for corresponding to the world food security and soaring of food price. Improvement of agricultural productivity is just urgent theme in SSA. In order to rehabilitate soil and water environment for crop growing, Kobayashi et al. were verified in 2009 that mulching with organic matters was effective for reducing evaporation from soil moisture. Particularly for the growth of the upland rice, the effect of mulching at both early growth and heading promotion was remarkably noticed.

However, recent research attention has been paid to pearl millet (*Pennisetum glaucum* (L.) R. Br.), which is one of the most popular cereal crops in SSA. So, this study aims to investigate the effects of stubble mulching with pearl millet stalk residues on pearl millet growth comparing with that of mixing soil with pearl millet stalk residues or non-treatment as control. The terminology of stubble mulching in this study means a soil covering system utilizing crop residues existed already in site.

MATERIALS AND METHODS

The experiment was carried out at the greenhouse of Tokyo University of Agriculture from May to October, 2009. Pearl millet was cultivated on each plot of 6.5 m long and 0.8 m wide (Fig.1). Nine plots were divided into 3 groups based on irrigation intensity; the first was irrigated at 3 to 6 mm/day as standard plots, the second at 2/3 of the irrigation amounts of standard plots as slightly water-saving plots and the third at 1/3 of the amounts of standard plots as water-saving plots. Each group was constituted with 3 different treatments; stubble mulching with pearl millet stalk residues, mixing soil with pearl millet stalk residues and non-treatment as control. Regarding stubble mulching, air-dried pearl millet stalk residues were cut at approximately 3 cm in length and arranged for covering soil in the plots. Also, air-dried and cut pearl millet stalk residues were applied for mixing with soil at a depth from 0 cm to 5 cm. Nothing was applied for non-treatment. Same amounts of pearl millet stalk residues at 2 kg was applied in each plot of stubble mulching or mixing treatment, and after 30 days the germinated pearl millet was transplanted zigzag in each plot at the interval of 0.8 m vertically and 0.2 m horizontally, approximately. Certain amounts of water were irrigated at 2 to 3 days interval. The irrigation amounts of standard plots were the same as that of standard cultivation of upland rice in Japan, and the irrigation amounts of 2/3 or 1/3 water-saving plots were estimated on the basis of the precipitation in Sahel-Sudan climate zone or Sahel climate zone, respectively.

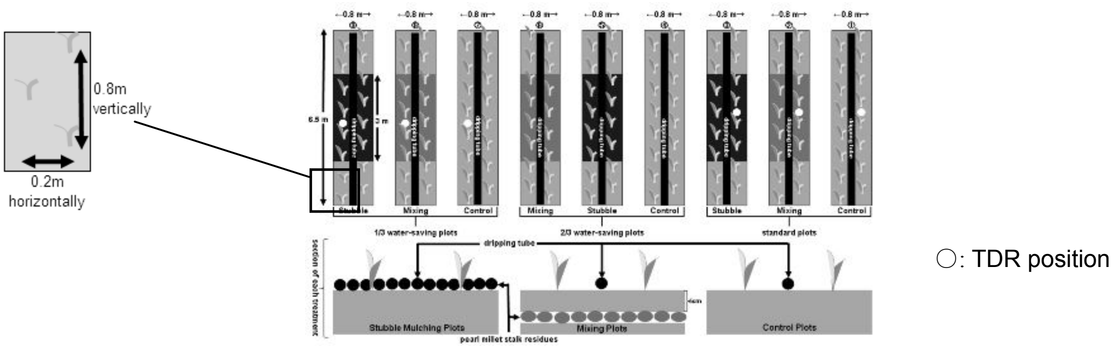


Fig. 1 Schematic diagram of the cultivation experiments and the section of each treatment

Fig. 2 Stubble mulching

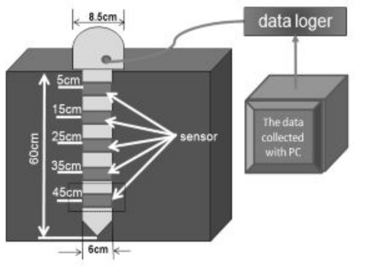


Fig. 3 Outline of the TDR system

Soil moisture was measured at certain interval with TDR to observe the changes in soil moisture. TDR has devices for accurate measurement of reflected electromagnetic signals (Or, O., and Wraith, J. M., 2000). The interval measuring soil moisture was 1 hour using SMART-Enviro (Sentek Pty, Ltd. 2005) with 5 TDR sensors (5 cm, 15 cm, 25 cm, 35 cm and 45 cm deep) as shown in Fig.3.

RESULTS AND DISCUSSION

Water was provided by drip irrigation method at 2 to 3 days interval. Among standard plots, the fluctuation of volumetric water content in the plot of stubble mulching was remarkably less than that of non-treatment as control (Fig.4).

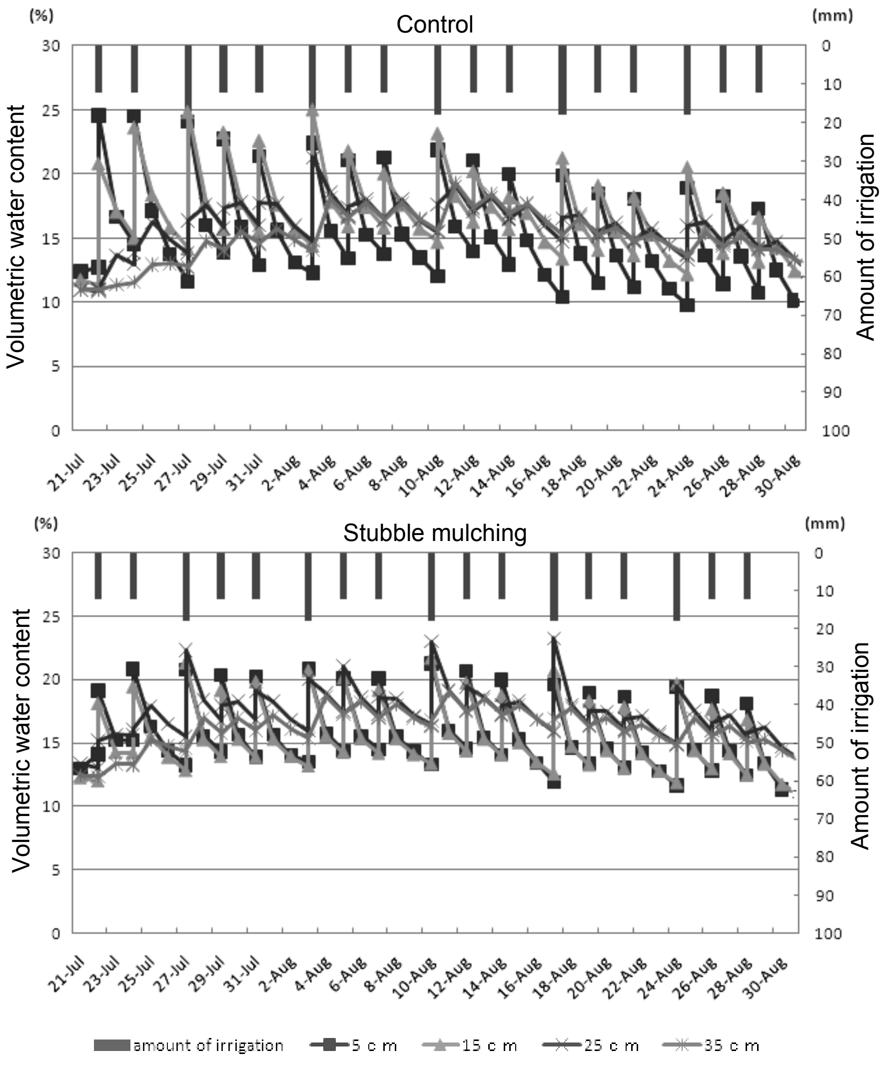


Fig.4 Changes in volumetric water content among standard plots

Regarding the growth of pearl millet, the plant height was measured periodically every 20 days from the third day of transplanting, also various plant weights of fresh, dry and spike ones were measured at the harvesting period. From the results of standard plots irrigated at 3 to 6 mm/day, there was a tendency for the plant heights of mixing soil with pearl millet stalk residues to be slightly higher than that in other treatments. However in the 1/3 water-saving plots, remarkable difference was not observed among the treatments; stubble mulching, mixing soil with pearl millet stalk residues and non-treatment as control (Fig. 5).

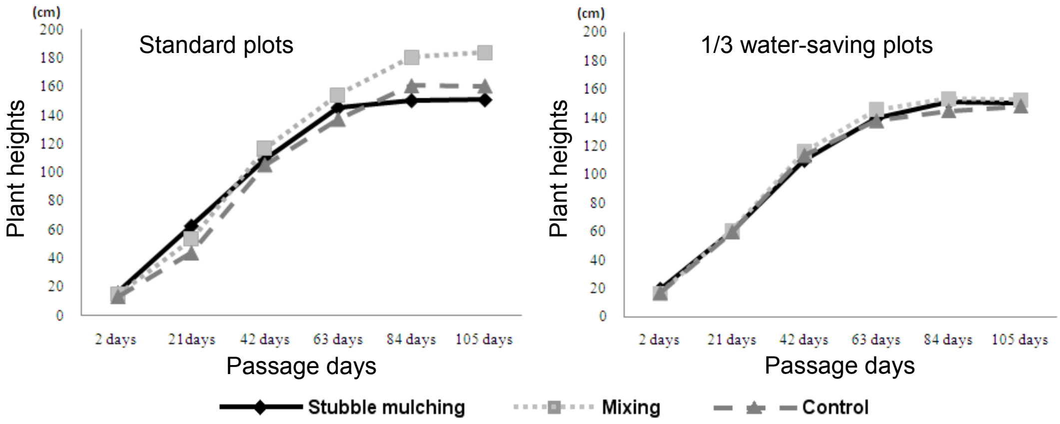
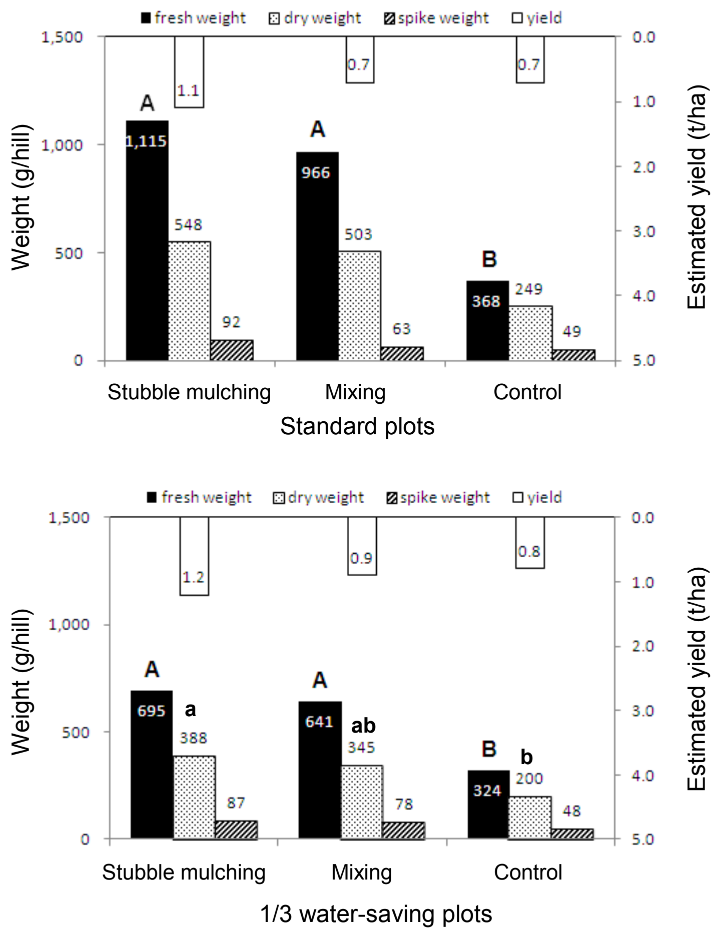


Fig.5 Changes in plant heights after transplanting

However, at both standard plots and 1/3 water-saving plots, there were tendencies for fresh, dry and spike weights in the plots of stubble mulching or mixing soil with pearl millet stalk residues to be remarkably higher than that of control (Fig.6).



**The data followed by different letters differs significantly at 95% confidence interval based on one-way factorial ANOVA analysis.*

Fig.6 Comparison of pearl millet growth under different treatments

Especially, the fresh weights of control at both standard plots and 1/3 water-saving plots were significantly lower than that of other treatments, stubble mulching or mixing soil with pearl millet stalk residues, at 95% confidence level based on one-way factorial ANOVA analysis (Fig.6). Additionally, there was a tendency for pearl millet growth in the plots of stubble mulching to be higher than that of mixing soil with pearl millet stalk residues, although a significant difference at 95% confidence level was not recorded.

Additionally, the yields under stubble mulching converted to the amounts per hectare were 1.1 t/ha and 1.2 t/ha for standard and 1/3 water-saving plots, respectively (Fig.6). It means the experimental results indicated approximately 2 times higher than the average yield at 0.451 t/ha of the Republic of Niger in FY2007 (Himeno et al, 2009).

CONCLUSION

This study dealt with the comparison in pearl millet growth among 3 different treatments as stubble mulching with pearl millet stalk residues, mixing soil with pearl millet stalk residues and non-treatment as control under 3 different irrigation intensities; the first was irrigated at 3 to 6 mm/day as standard plots, the second at 2/3 of the irrigation amounts of standard plots as slightly water-saving plots and the third at 1/3 of the amounts of standard plots as water-saving plots. The irrigation amounts of 2/3 or 1/3 water-saving plots were estimated on the basis of the precipitation in Sahel-Sudan climate zone or Sahel climate zone, respectively.

The results from non-treatment indicated that plant growth in pearl millet above ground surface did not show a significant difference among the plots of different irrigation amounts. However, the fresh weights of control at both standard plots and 1/3 water-saving plots were significantly lower than that of other treatments as stubble mulching or mixing soil with pearl millet stalk residues at 95% confidence level. Additionally, there was a tendency for pearl millet growth in the plots of stubble mulching to be higher than that of mixing soil with pearl millet stalk residues, although a significant difference at 95% confidence level was not recorded.

Accordingly, it was concluded the utilization of stubble mulching in the production of crops under low rainfall condition such as Sub-Saharan Africa is expected to play beneficial roles such as improving soil moisture condition and plant growth.

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REFERENCES

FAO (2000) Sahel Weather and Crop Situation Report, No.1.

Himeno, K., Inoue, N., Ito, O., Kobayashi, Y., Kurauchi, N. and Nishikawa, Y. (2009) Minor cereals in Niger, Focusing on pearl millet and sorghum, Tropical Crops Handbook, Japan Association for International Collaboration of Agriculture and Forestry.

Kobayashi, Y., Yato, S., Fujikawa, T., Nakamura, T., Mihara, M. and Komamura, M. (2009) Study on Stable Mulching as Effective Water Saving Practice, Journal of Arid Land Studies, 19(1), 309-312.

Or, O. and Wraith, J.M. (2000) Soil Water Content and Water Potential Relationships, Handbook of Soil Science, A53-85.

Sentek Pty, Ltd. (2005) SMART-Enviro, Japanese Edition Manual, TWC.

UNFPA (2008) State of World Population, United Nations Population Fund.

WFP (2009) http://www.wfp.or.jp/hungermap/, 2009/10/12.

Research article

Environmental Risk Assessment of Agrochemical Packaging Waste in Northeast Thailand

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Abstract Thailand is a predominantly agricultural country where the majority of people earn a living by agriculture. Rapid agricultural growth in recent decades leads to high use of agrochemical. Lack of packaging management has created an environmental risk from pesticide residues. The objective of this study was to monitor the environmental risk from agrochemical packaging waste in Northeast, Thailand. Farmers from 4 villages in Bung-nium, Khon Kaen Province were interviewed using a questionnaire together with the study of diffuse pollution from agrochemical waste in soil and water. The pesticides used in every step of agricultural production followed in decreasing order: organophosphate, pyrethroid, carbamate, organochlorine, thiocarbamate, paraquat, and others, respectively. Agrochemical package waste investigated included foil bags, glass bottles, gallon plastic containers, plastic bottles, paper bags, carton, aluminum bottles and woven sacks. Glass bottle and plastic container were found in higher proportion. Most of agrochemical package waste was disposed in unattended repositories in the field such as under trees or in pits. The outcome of this study is useful for agrochemical waste management and seeks to reduce the diffuse pollution of agrochemical waste to environment.

Keywords environmental risk assessment, agrochemical packaging waste

INTRODUCTION

Thailand is a predominantly agricultural country, at majority people earns a living by agriculture such as rice, flowering plant, the garden tree, fruit, and vegetables. Land use for agriculture area in Northeast Thailand covered approximately 77.58% of the total area. Dominant land use includes rice of about 55.12% and other crops of about 22.03% (by visual interpretation form Landsat in 2000-2002) (Mongkolsawat, 2006). The agricultural growth leads to high use of agrochemical which is significant and necessary for crop production to fulfill the requirement of consumer. The first synthetic pesticides became available during the 1940s, generating large benefits in increased food production. Concern about the adverse impacts of pesticides on the environment and human health started being voiced in the early 1960s (Carson, 1962)

The total amount of imported agrochemicals of Thailand in 2007 and 2008 are 67,895 and 66,563 tons, respectively (Department of Agriculture, 2009). The more pesticide use, the more the waste or agrochemical package waste, as it large amounts of hazard waste and difficult to management such as glass bottle, gallon, plastic bucket, paper box and sack. The lack of management in Thailand and uncontrolled discharge of package waste with a burn can release a green house gas and hazardous gas into the air and influence on climate change. Agrochemical packaging waste is considered as hazardous material containing agrochemical residues that would not be used. Therefore, most of agrochemical packaging wastes were disposed unattended. Agrochemical waste includes surplus spray solutions, agrochemical leftover which remains in the application equipment after use, pesticide contaminated water produced by cleaning the application equipment or from rinsing the empty pesticide containers, agrochemical contaminated materials generated from cleaning up spilled pesticides, empty (unrinsed) pesticide containers, and old pesticide products (Nesheim and Fishel, 2005).

Therefore, the study to environmental risk assessment of agrochemical packaging waste using questionnaire was monitored cooperate with survey and soil, sediment and water analysis in order to the best management and reduce the diffuse pollution from agrochemical package waste residue.

MATERIALS AND METHODS

Sampling Area

Field study areas were conducted in Bung-niam sub-district, Muang district, Khon Kaen province. The Bung-niam is located at the part of Pong watershed in Northeast Thailand**,** covers a total area of 41.233 km^2, and has a population of 7,273 habitants and 1,576 household (1,171 household of agriculture) and Global Positioning System (GPS) location is 16º24'23"E, 102º56'50"N (Fig.1).

Fig. 1 Map of the location of Bung-niam

Analytic methods

The survey was used with the questionnaire from four villages in Bung-niam. The environmental risk assessment of agrochemical packaging waste was studied. The soil and water quality were analyzed. The water samples were collected by grab sampling, and analyzed for the physical and chemical parameters such as pH, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS) and temperature. And sediment samples were collected at random, and analyzed for the physical and chemical parameters such as soil texture, pH, EC, organic matter and pesticide residue.

Water chemical analysis

Water pH, EC and temperature were measured with a pH, EC meter and thermometer respectively, DO was measured by Winkler (Azide modification) by adding $MnSO_4$ following AIA (Alkali-iodide-azide) and then titrated with standard 0.025 N sodium thiosulfate. The measurement of TDS was determined gravimetcically by filtering and drying at 103-105 °C and then weighing. Samples were analysed according to the last edition of the Standard method for Examination of Water and Wastewater procedure (APHA, AWWA and WEF, 1992).

Sediment sampling physical and chemical analysis

Soil sample was mixed and sieved (2 mm). Soil pH and EC were measured in a 1:5 soil to water solution using a glass electrode. Particle size analysis was done by pipette method. Organic matter was analyzed by dichromate oxidation method, pesticides residue: Carbamate group was analysed in method based on QuEChERS by HPLC/ Postcolumn derivatizer, Organochlorine group and Pyrethroid group were in house method based on QuEChERS by GC-μECD, and Organophosphate was in house method based on QuEChERS by GC-FPD.

Statistical analysis

Statistical analysis including calculation of average values, standard deviation (S.D.) and regression was performed on the data obtained in the tests with Microsoft Excel.

RESULTS

Pesticide residues in the sediment in the study area were shown in Table 1. The result showed that the organophosphate group of pesticides was found too much in sediment. This finding was correlated with the pesticide uses in this area (from the survey data).

Table 1 Pesticide residue in sediment

Pesticides residue	Pesticides in sediment	Pesticides residue	Pesticides in sediment
Carbamate group (µg/kg)		**Organochlorine group (µg/kg)**	
Aldicarb sulfoxide	0.013	alpha-HCH	0.0002
Aldicarb sulfone	0.012	beta-HCH	0.0002
Oxamyl	0.016	gamma-HCH	0.0002
Methomyl	0.010	Heptachlor	0.0002
3-Hydroxy Carbofuran	0.021	Aldrin	0.0002
Aldicarb	0.014	Dicofol	0.0024
Carbofuran	0.021	Heptachlor Epoxide	0.0002
Carbaryl	0.010	gamma-chlordane	0.0002
Fenobucarb	0.018	2,4-DDE	0.0003
Methiocarb	0.023	alpha-Endosulfan	0.0002
		alpha-chlordane	0.0002
Organophosphate (µg/kg)		Dieldrin	0.0001
Dichlorvos	0.546	4,4-DDE	0.0003
Methamidophos	2.077	2,4-DDD	0.0003
Mevinphos	0.708	beta-Endosulfan	0.0002
Omethoate	5.031	Endrin	0.0002
Diazinon	0.389	2,4-DDT	0.0007
Dicrotophos	1.877	4,4-DDD	0.0024
Monocrotophos	4.958	Endosulfan sulfate	0.0004
Dimethoate	1.676		
Pirimiphos-methyl	0.441	**Pyrethroid group (µg/kg)**	
Chlorpyrifos	0.483	Bifenthrin	0.0008
Parathion-methyl	1.238	Cyhalothrin	0.0003
Pirimiphos-ethyl	0.434	1 Permethrin I	0.0021
Malathion	0.961	1 Permethrin II	0.0021
Fenitrothion	0.874	2 Cyfluthrin I	0.0004
Parathion-ethyl	0.454	2 Cyfluthrin II	0.0004
Prothiophos	0.530	2 Cyfluthrin III	0.0004
Methidathion	2.834	2 Cyfluthrin IV	0.0004
Profenofos	1.141	3 Cypermethrin I	0.0006
Ethion	0.335	3 Cypermethrin II	0.0006
Triazophos	0.953	3 Cypermethrin III	0.0006
EPN	1.021	3 Cypermethrin IV	0.0006
Phosalone	4.662	4 Fenvalerate I	0.0006
		4 Fenvalerate II	0.0006
		Deltamethrin	0.0007

The surveying study with questionnaire to the farmers from 4 villages in Bung-nium district, Khon Kean found that the most use of pesticide was organophosphate, followed by pyrethroid, carbamate, organochlorine, thiocarbamate, paraquat, and others. The pesticide was used in every step of agricultural crop production. Agrochemical package waste was found in different form of container such as foil bags, paper bags, plastic bags or plastic sacks, glass bottle, plastic bottles, tank or gallon plastic, carton and aluminum bottles. Glass bottle and plastic container were found in higher proportion compared with other types. Most of agrochemical package waste was dispose unattended in the field such as under the tree or dig under the ground (Table 2). The meteorology of study site, characteristics of sediment and water were shown in Table 3.

Table 2 The management of agrochemical packaging waste

Agrochemical package waste	Embedded (%)	Sell (%)	Reuse (%)	Discard (%)	Waste into the water (%)	Burn (%)
1. Foil bags	11	4	11	6	-	18
2. Paper bags	13	7	-	10	-	36
3. Plastic bags or woven sacks	13	7	44	16	-	27
4. Glass bottles	16	24	11	26	-	-
5. Plastic bottles	18	19	11	23	-	-
6. Gallon plastic	7	10	22	3	-	-
7. Carton	11	12	-	6	-	18
8. Aluminum bottles	11	16	-	10	-	-

Table 3 Information about the field site

Type of data	Description	Value (average)
Meteorology of field site	Rainfall in 2008 (mm/month)	141.57
Characteristics of Sediment	Soil texture	Loamy sand
Characteristics of water	Organic matter (%)	0.59
	pH	6.01
	Temperature (ºC)	23.8
	TDS (ppm)	101
	DO (mg/L)	1.51
	pH	8.35
	EC (µS/cm)	200
	Temperature (ºC)	33.5

CONCLUSION

The disposal of agrochemical package waste is a significant problem of waste disposal in Thailand. The management of agrochemical waste disposal is needed and important part of responsible pesticide use. Improper disposal can lead to contamination of soil and water, causing serious problems for people who involved with the pesticide use. The impact of this waste on ecosystem and environment should be studied. The farmer training programs should be conducted to raise the awareness of farmers on the hazards of pesticide use and how to manage agrochemical waste properly. Damalas et al. (2008) suggested that the proper management of waste products, recycling programs and collection systems for unwanted agricultural chemicals to prevent inappropriate waste disposal, as well as improving packaging of pesticides to minimize waste production are essential for promoting safety during all phases of pesticide handling.

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REFERENCES

APHA, AWWA and WEF (1992) Standard Methods for the Examination of Water and Wastewater. American Public Health Association, New York, USA.

Carson, R.L. (1962) Silent spring. Riverside Press, Cambridge, USA.

Damalas, C.A., Telidis, G.K. and Thanos, S.D. (2008) Assessing farmers' practices on disposal of pesticide waste after use. Science of the total environment, 390, 341-345.

Department of agriculture (2009) The total amount of imported agrochemicals of Thailand. http://www.chiangmainews.co.th/viewnews.php?id=10009&lyo=1.

Mongkolsawat, C. (2006) Northeast Thailand Spatial Potentials for Development. Geo-informatics centre forthe development of Northeast Thailand, Faculty of Science, Khon Kaen University, Thailand.

Nesheim, O.N. and Fishel, F.M. (2005) Proper disposal of pesticide waste. Florida Cooperative Extension Service, University of Florida, PI-18, UAS.

Research article

Soil Biota Activities Relation with Soil Characteristics in the Improved Salt-affected Area by Tree Plantation

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Abstract Salt affected soil is a serious problem in Thailand, particularly in the Northeast Plateau where salt bearing rocks are abundant. Excessive amounts of salts have a range of adverse effects on the physical and chemical properties of soil microbiological processes and plant growth. However, soil biological aspect of saline environment has been less studied. Tree Plantation has been introduced to improve salt-affected area. Monitoring of the changes by study the soil biota activities relation with physical and chemical soil characteristics are important. The aim of this study was to monitor the change of soil biota activity relation with the soil properties in the improved salt-affected area by Tree Plantation at Amphur Borabue, Mahasarakam Province, Northeast of Thailand. The physical, chemical and biological soil characteristics in soil sample were analyzed before and after tree plantation. The results showed that soil biota activity after tree plantation was higher than before. Soil respiration before and after tree plantation were 12.13 and 71.50 mg CO2/day, respectively. The EC, Na, K, and CEC values were decreased and pH, OM, and N were increased after tree plantation. The result from this study indicated that physical, chemical and biological properties were improved after tree plantation. This study's result would be useful for sustainable land resources improvement and rehabilitation.

Keywords salinity, soil biota, salt affected area, soil characteristics

INTRODUCTION

Salt affected soil is a serious problem in Thailand, in the Northeast Plateau where salt bearing rocks are common (Department of Land Development, 1991). Salt affected soils are extensively developed in many areas in Northeast Thailand such as Nakhon Ratchasima, Khon Kean, Roi Et and Mahasarakham Provinces (Department of Mineral Resources, 1982). Soil salinity generally occurs in discharge areas where the water table is high including edges of closed depressions and low lying areas where evaporation is high and high salt concentrations develop (Wongpokhom et al., 2007). Salinity has a range of adverse effects on the physical and chemical properties of soil, microbiological processes and plant growth. While the effects of salinity on soil chemical and physical properties and plant growth are well documented, the studies on their effects on soil biota activities are limited (Yuan et al., 2006). Salinity show harmful influence on the size and activity of the soil microbial biomass and on biochemical processes essential for maintenance of soil quality. This will result in a reduction in the rate of soil organic matter decomposition and in plant available nutrients, which further limits plant growth and crop production in salt affected soils. Therefore, ecological monitoring of the change of soil physical, chemical and biological changes in the salt-affected area after tree plantation in Northeast Thailand is needed.

The objectives of this study were to monitor the change of soil biota activities in relation with the physical and chemical properties of soil in the salt-affected area before and after tree plantation.

MATERIALS AND METHODS

Study site

The study was conducted in at Ak-Kasatsuntorn water reservoir, Tumbon Borabue, Mahasarakam Province, Thailand. The site is located between latitude of $16^{0}0^{'}47.4^{''}$N and longitude of $103^{0}5^{'}23.8^{''}$E.

Soil sampling and analysis

The study area was divided into 3 zones followed by the plant community found in each area which correlated with the flooding situation and soil salinity. Soil samples from each zone were collected in year 2008. Soil physical and chemical properties were measured. The impact of salinity on soil biota was studied by Basal respiration for microbial activity followed by Anderson method (Anderson, 1982). After carefully removing the surface organic materials and fine roots, each composited moist field soil sample was mixed, homogenized and sieved through a 2 mm mesh screen. Microbial and biochemical analyses were carried out on field moist subsamples, and physicochemical analyses were performed on air dried subsamples. Soil pH and EC were measured in a 1:5 soil to water solution using a glass electrode. Particle size analysis was done by pipette method. Organic C was analyzed by dichromate oxidation method. Total N was estimated by Kjeldahl method. Extractable NO_3 and NH_4 were measured in 2 MKCl extracts of the soil using a Lachat autoanalyzer. Total K in the extract from the 35% HF and 60% $HClO_4$ digestion of the soil and available K with 1 M NH_4OAc were determined by flame photometry. Available P in the extract with 0.5 M $NaHCO_3$ by the Olsen method and total P with 60% $HClO_4$ digestion of the soil were measured colorimetrically. Microbial biomass C and biomass N were estimated by the chloroform fumigation extraction method. Six portions equivalent to 25 g oven dry soil were taken from each soil sample. Three portions were fumigated for 24 h at 25 ^{o}C with ethanol free $CHCl_3$. Following fumigant removal, the soil was extracted with 100 ml 0.5 M K_2SO_4 by horizontal shaking for 1 h at 200 rpm and then filtered. The other three non-fumigated portions were extracted simultaneously at the time fumigation commenced. Organic C in the extracts was measured using the dichromate oxidation method. Microbial biomass C was calculated as follows: microbial biomass C = EC/kEC, where EC = (organic C extracted from fumigated soils) - (organic C extracted from non-fumigated soils) and kEC = 0.38. Total N in the extracts was measured using the Kjeldahl method. Microbial biomass N was calculated as follows: microbial biomass N = EN/kEN, where EN = (total N extracted from fumigated soils) - (total N extracted from non-fumigated soils) and kEN = 0.54 (Yuan et al., 2006). Basal respiration was determined by placing 30 g of field moist soil in a 50 ml beaker and incubating the sample for 1 day in the dark at 25 ^{o}C in a air tight sealed jar along with 10 ml of 1 M NaOH. The CO_2-C evolved was determined after 1 day by titration (Anderson, 1982). Basal respiration rate was calculated based on CO_2 evolution over the 1 day period. The microbial metabolic quotient was calculated as basal respiration (mg CO_2) per mg of microbial biomass C (Anderson and Domsch, 1990).

Statistical analysis

An analysis of a variance (ANOVA) was used to compare each zone and the impact on soil biota activites by Statistix 8.

RESULTS AND DISCUSSION

The soil physical and chemical properties before and after tree plantation were shown in Table 1 and 2. The result found that the physical, chemical and biological soil properties were improved after tree plantation. The EC, Na, K, CEC values were reduced and pH, OM, and N were increase significantly differences after tree plantation ($p<0.05$). Soil biota activity after tree plantation was higher than before plantation significantly ($p<0.05$). Soil respiration before and after tree plantations were 12.13

and 71.50 mg CO_2/day, respectively (Table 3). There was a significant increasing in the microbial biomass C after tree plantation ($p<0.05$) (Table 3).

Table 1 The physical properties of soil in different zone at salt-affected area before and after tree plantation

Sampling site	Before	After	Percent Change (%)
Moisture	9.66 a	15.01 b	55.38

Values indicated by different letters in the same row are significantly different ($P \leq 0.05$).

Table 2 The chemical properties of soil in different zone at salt-affected area before and after tree plantation

Sampling site	Before	After	Percent Change (%)
pH (1:5)	5.59 a	5.67 a	1.52
EC (1:5) (dS/m)	0.573 a	0.019 b	-96.68
OM (%)	0.44 a	0.49 b	10.48
Total N (%)	0.018 b	0.087 a	384.72
Available P (ppm)	10 a	6 a	-36.93
Extractable K (ppm)	144 a	27 b	-81.04
Extractable K (c mol(+)/kg)	0.625 a	0.118 b	-81.2
Extractable Na (ppm)	276 a	161 a	-41.56
Extractable Na (c mol(+)/kg)	0.706 a	0.412 a	-41.6
CEC (c mol(+)/kg)	3.67 a	3.18 a	-13.3

Values indicated by different letters in the same row are significantly different ($P \leq 0.05$).

Table 3 The basal soil respiration of soil and soil microbial biomass C, N of soil in different zone at salt-affected area

Sampling site	Before	After	Percent change (%)
CO_2	12.13 a	71.50 b	494.75
MBC	67.46 a	172.32 b	155.44
MBN	81.98 a	25.59 b	-68.79

Values indicated by different letters in the same row are significantly different ($P \leq 0.05$).

The relationships with EC demonstrate the highly detrimental effect that soil salinity had on the microbial activity. The study of Yuan et al. (2006) about the effects of salinity on the size, activity and community structure of soil microorganisms in salt affected arid soils were investigated in Shuangta region of west central Anxi County, Gansu Province, China. Eleven soils were selected which had an electrical conductivity (EC) gradient of 0.32-23.05 mS cm^{-1}. There was a significant negative exponential relationship between EC and microbial biomass C, the percentage of soil organic C present as microbial biomass C, microbial biomass N, microbial biomass N to total N ratio, basal soil respiration, fluorescein diacetate (FDA) hydrolysis rate, arginine ammonification rate and potentially mineralizable N. The exponential relationships with EC demonstrate the highly detrimental effect that soil salinity had on the microbial community. In contrast, the metabolic quotient (qCO_2) was positively correlated with EC, and a quadratic relationship between qCO_2 and EC was observed. Soil microbial biomass has been used to compare natural and disturbed ecosystems. Microbial biomass C was lowest in those soils where CO_2-C emission was also low.

This suggests that in salt affected soils biomass C can serve as a sensitive indicator of changes in soil organic matter and it is one of the general indices to soil microbial activities (Wick et al., 1998). Since basal respiration represents the living component of microbial biomass C (Sparling, 1992), our study shows that the biological activity in soil in salt affected area were increasing after tree plantation.

CONCLUSION

It is obvious that salinity not only had adverse effects on soil physical and chemical properties and crop growth but also on the soil biota activity which is essential for maintenance of soil fertility. Tree plantation in the salt-affected area can improved physical, chemical and biological soil characteristics. Monitoring of the ecosystem changes in salt affected area by studying the soil biota activities is important. The result of this study would be useful for land resources improvement and rehabilitation.

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REFERENCES

Anderson, J.P.E. (1982) Soil respiration. In A.L. Page, R.H. Miller and D.R. Keeney (Eds), Methods of soil analysis, Part 2, Chemical and microbiological properties, 9, American Society of Agronomy, Wisconsin, USA, 831-871.

Anderson, J.P.E. and Domsch, K.H. (1990) Application of eco-physiological quotients (qCO_2 and qD) on microbial biomass from soils of different cropping histories, Soil Biol. Biochem., 22, 251-255.

Department of Mineral Resources (1982) Geologic map of Thailand. Department of Mineral Resources, Bangkok, Thailand.

Department of Land Development (1991) Distribution of salt affected soil in the northeast region 1:100,000 map. Department of Land Development, Bangkok, Thailand.

Sparling, G.P. (1992) Ration of microbal biomass to soil organic carbon as a sensitive indicator of changes in soil organic matter. Aust. J. Soil Res, 30, 195-207.

Wick, B., Kuhne, R.F. and Vlek, P.L.G (1998) Soil microbiological parameters as indicators of soil quality under improved fallow management systems in south western Nigeria. Plant Soil, 202, 97-107.

Wongpokhom, N., Kheoruenromne, I., Suddhiprakarn, A. and Gilkes, R.J. (2007) Micromorphological properties of salt affected soil in Northeast Thailand. Geoderma, 144, 158-170.

Yuan, B., Li. Z., Liu, H., Gao, M. and Zhang, Y. (2006) Microbial biomass and activity in salt affected soil under arid condition. Applied Soil Ecology, 35, 319-328.

Research article

Piggery Farm Wastewater: Alternative Solution for Agriculture and Soil Fertility

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Abstract The consequences of piggery farm are increasing public concern particularly, wastewater because of its high pollutant potential. Without the good wastewater treatment systems, it could lead to contaminate the natural water resources nearby. The number of the small and medium size of piggery farms could not afford the wastewater treatment cost. The wastewater management is needed. The objective of this study aims to evaluate the water quality characteristics from the piggery farm in Northeast of Thailand and feasibility study of using wastewater from piggery farm for agriculture purpose. The wastewater from influent, effluent from the system and wastewater before release to natural waterway were sampled and analyzed for water characteristics in term of pH, Temperature, Electrical Conductivity (EC), Total Kjeldahl Nitrogen (TKN), Total Total Phosphorus (TP), Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solid (TDS), Fat OilandGrease (FOG), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and other heavy metal contaminants such as Zinc (Zn), Lead (Pb), Cadmium (Cd) and Cupper (Cu). The results found that the wastewater had high potential to pollute the natural waterway. However, some water quality characteristics such as N and P may be the source of good nutrients for agriculture production and increasing soil fertility. Therefore, using piggery farm wastewater for agriculture may be one of alternative solution for soil fertility and wastewater management.

Keywords piggery farm wastewater, agriculture, soil fertility

INTRODUCTION

There are 10 million Piggery farms in Thailand in 2007 and increase to 13 million farms in following year due to the high demand of pork product. Therefore, the waste from piggery farm has been increased followed the piggery farm. The consequences of piggery farm are increasing public concern particularly, wastewater because of its high pollutant potential. The wastes from piggery farm are difficult to manage compared with the waste produced in each day (Noophan, 2009; Department of Livestock, 2007). It could lead to contaminate the natural water resources nearby (Srilachai et al., 2007). Wastewater characteristics in form of BOD and COD were about 1,500-3,000 mg/L and 4,000-7,000 mg/L respectively. Piggery farm wastewater has high of NO_3-N and NH_4-N, through 60-70% of organic nitrogen and wastewater could replace chemical fertilizers as much as 80-100% of the application rate depending on type of growing crops (Panichsakpatana, 2006). In wastewater is widely used as fertilizer in many countries because of its high organic, nitrogen and phosphorus content (Deng et al., 2006).

The utilization of wastewater from biogas in piggery farm helped to increased height and seed yield of corn significantly, and increases the accumulation of P, K, and Mg in soil. Moreover, Cu and Zn in pig manure did not accumulate in soil (Aoungsawad, 1999). The effluent form biogas cloud substitute the irrigation water as much as 40,000 L/rai/week for the whole growing period (1 hectare = 6.25 rai). With the mentioned rate, there was no change in some chemical and physical properties of the soil (Panichsakpatana, 1995). However, the impact of wastewater reuse on land application in

Northeast of Thailand was less studied. The objective of this study aims to evaluate the water quality characteristics from the piggery farm in Northeast of Thailand and feasibility study of using wastewater from piggery farm for agriculture purpose and it may be one of alternative solution for soil fertility and wastewater management.

MATERIALS AND METHOD

Grab samples of piggery farm wastewater from large-scale piggery farm in Northeast of Thailand were studied. The study site of piggery farm is located in Khon Kaen province (Coordinate: 15°58'15"N 102°49'16"E). The number of pig was about 9,645 in this farm and wastewater treatment system was UASB anaerobic type. Sampling the wastewater from influent, effluent from the system and wastewater before release to natural waterway was monitored every month (Fig.1). Three samples per sampling sites were collected. The samplers were taken to the laboratory and analyzed water characteristics immediately. The characterization of physical chemical and biochemical properties of wastewater characteristics were analyzed following the method of APHA-AWWA-WEF and EEAT of Thailand (1998).

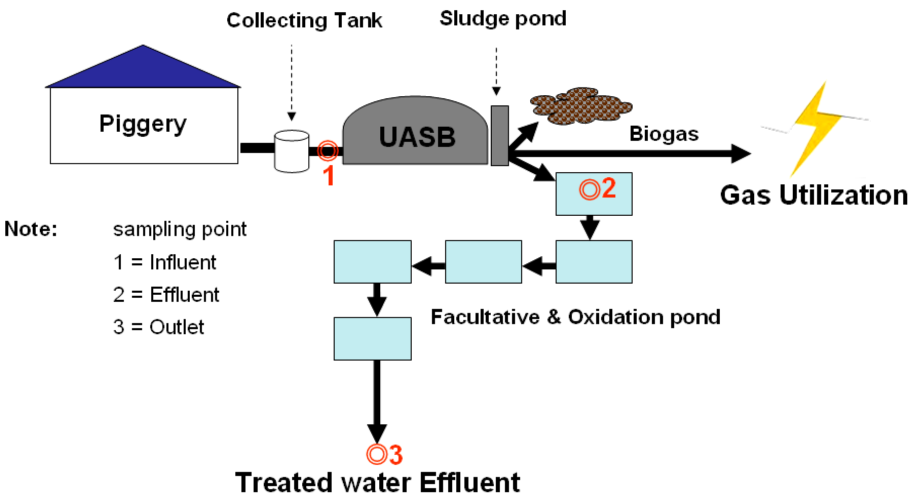

Fig.1 The study site and sampling points

RESULTS

Piggery farm wastewater from influent, effluent from the system and wastewater before release to natural waterway were showed in term of water characteristics in Table 1. The result showed that water quality in most of water parameters were better from the beginning and after the treatment process, except pH and CEC which have higher values before release to natural waterway. The reason for these may be because of the soil texture in this area has sand or loamy sand and high gradient erosion and salt (Land development department, 2008).

The wastewater from every study sites had high value of organic and N as well as BOD, COD, N and P which caused water pollution in areas with intensive animal farming, phosphorus from livestock waste contributes to the eutrophication of surface water (Daumer et al., 2007). However, another point of views, the beneficial of wastewater form piggery farm could be used for agriculture and plant production. In particular, when look at the high value of N about 284.20-481.04 mg/L and P 24.50-79.98 mg/L from influent and wastewater before release to natural waterway could be used as N and P fertilizer source. The results from this study shows that the wastewater from this piggery farm could substitute Nitrogen and Phosphorus fertilizer by producing nitrogen 29-50 kg/day and phosphorus 3-8 kg/day. Therefore, the utilization of piggery farm wastewater for agriculture may be one of alternative solution for soil fertility.

Table 1 Water quality of piggery farm

Parameters	Result[1]		
	Influent	Effluent	Outlet
pH	7.4±0.05	7.8±0.05	8.0±0.05
Temperature (°C)	29±0.00	37±0.00	30±0.00
EC (dS/m)	6.9±0.05	7.7±0.01	8.0±0.05
TKN (mg/L)	481.04±2.02	458.92±0.10	284.20±0.20
TP (mg/L)	79.98±0.10	44.34±0.98	24.50±0.50
TS (mg/L)	5,100±6.58	2,250±10.00	190±5.00
TSS (mg/L)	2,317±5.10	1,200±624	24±2.45
TDS (mg/L)	2,783±10.39	1,050±7.00	165±4.58
FOG (mg/L)	130±1.73	85±5.00	30±5.00
COD (mg/L)	4,889±6.58	698±2.65	254±5.52
BOD (mg/L)	3,555±5.00	67±4.00	59±2.65
Zn (mg/L)	-	-	0.0930±0.001
Pb (mg/L)	-	-	0.0022±0.000
Cd (mg/L)	-	-	0.0360±0.000
Cu (mg/L)	-	-	<0.0002±0.000

[1] values are means (n = 3)

There was an example study of applying only wastewater in sugar cane production compared with chemical fertilizer and the result found that there were no significantly effects on sugar cane production. The diameter of stem and sweetness of sugar cane were similar to the one applied with chemical fertilizer (Techaviriyataveesin, 2004). Not only waste water could increase soil fertility and wastewater could be used as an alterative source of water for plant growth. It could substitute the irrigation water as 40,000 L/rai/week or 280,000 L/rai for the whole growing period (1 hectare = 6.25 rai) (Panichsakpatana, 1995) .

CONCLUSION

The results found that the wastewater from piggery farm has high potential to pollute the natural waterway. However, some water quality characteristics such as N and P may be the source of good nutrients for agriculture production and increasing soil fertility and could substitute the irrigation. The results of these study showed that the amount of wastewater per day was 103,350 L and nitrogen and phosphorus in wastewater were 29-50 kg/day and 3-8 kg/day, respectively. Therefore, using piggery farm wastewater for agriculture may be one of alternative solution for soil fertility and wastewater management.

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REFERENCES

Aoungsawad, K. (1999) The study on the usage of wastewater from pig farm for agriculture. Faculty of agriculture, Chiang Mai University, Chiang Mai, Thailand.

Daumer, M.L., Béline, F., Guiziou, F. and Sperandio, M. (2007) Influence of pH and biological metabolism on dissolved phosphorus during biological treatment of piggery wastewater. Biosystems Engineering J., 96, 379-386.

Deng, L.W., Zheng, P. and Chen, Z.A. (2006) Anaerobic digestion and post-treatment of swine wastewater using IC-SBR process with bypass of raw wastewater. Process Biochemistry J., 41, 965-969.

Department of Livestock (2007) Piggery farm database in Thailand. http://www.dld.go.th/ict/yearly/yearly49/stat/annex05.xls.

Land Development Department (2008) Soil series characteristics and management. http://www.ldd.go.th/web_study_center/khoahinson/kazadsub/ka_soil.asp.

Noophan, P. (2009) The piggery waste problem and sustainable approach management. Thai environmental engineering magazine, 5, 19-25.

Pollution Control Department. (2008) Sampling technique for good laboratory. Ministry of Natural Resources and Environment, Bangkok, Thailand.

Panichsakpatana, S. (2006) Recycling of wastewater from pig farms in urban and peri-urban agriculture. http://agent.org/activities/sw/2006/729863362/paper-556441822.pdf.

Panichsakpatana, S. (1995) Utillization of effluent from biogas production as nitrogen source for Pak-choy (*Brassica camperstris* var *chenensis*) grow on Kamphaeng Saen soil. Kasetstart J., 29(2), 445-453.

Srilachai, S., Wongpan, P. and Kuna-ek, V. (2007) Application of the appropriate wastewater treatment for small-sized pig farm. Environment Research and Training Center, Ministry of Natural Resources and Environment, Bangkok, Thailand.

Techaviriyataveesin, S. (2004) Utilization efficiency of wastewater from pig farm as fertilizer for sugar cane var. K 88-92 grown on sandy loam soil. M.S. Thesis, Kasetsart University, Thailand.

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.

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 publish the International Journal of Environmental and Rural Development, and
- to encourage and develop local awareness concerning sustainable rural development.

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