*Research article*

# Factors Affecting Rice Production in Northeastern Thailand: The Relationship between Soil Salinity and Vegetative Cover

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**Abstract** Saline soil is typically found in lower elevation terrain which is also used for rice cultivation. Deforestation in recharge areas can accelerate soil salinity due to increased capillary action. This study examined the relationship between saline soil distribution and vegetative cover at Nong Due Village, Khon Kaen, Thailand. It also identified some social factors and farm management practices which affected rice production in saline paddies. A field survey was conducted in April, 2012 to determine soil property analysis, combined with a questionnaire on rice production, farm management, and farmer's household socioeconomic conditions. In total, 34 paddy fields were surveyed with 68 soil samples collected from non-saline and saline plots. Elevations of the sampled plots were 146-178 m with electrical conductivity (ECe) 0.19-16.58 dS/m. Soil salinity did not show a significant correlation from the sampled paddies to the closest vegetation, but high salinity did occur in lower elevations and farther away from the nearest forest. Forty household representatives answered the questionnaire, of which 34 had encountered some problems with soil salinity (average 0.89 ha/household). Average rice yields from saline paddies were 1.9 tons/ha, lower than those from non-saline paddies (mean difference -113.39 kg/ha). Rice production costs associated with soil salinity were estimated 10,770 Baht/ha, of which the highest amount was spent on crop maintenance. In contrast, costs from non-saline farming systems were 9,791 Baht/ha (39.75% also spent on farm maintenance). Household income and labor did not show a significant correlation with farm management practices. Fertilizer application is dependent on the availability of on-farm resources and word-of-mouth. Farmers often use cattle manure, compost and green manure to reduce soil salinity. Moreover, farmers raised the height of paddy borders, so that more rainwater could be stored, thus ensuring that the rice paddies were continuously submerged.

**Keywords** soil salinity, saline paddies, vegetative cover, rice production, Nong Due village

## INTRODUCTION

Soil salinity is a major problem in semi-arid or arid regions around the world. For example, Arunin (1996) reported 17.81 million ha of salt-affected areas in northeastern Thailand (approximately 17% of the region). According to Yuvaniyama (2003), two important factors that cause saline soil distribution are: 1) the presence of salt rock in Maha Sarakham geological formation which induces salt-dissolved water to the topsoil through capillary action; and 2) land use activities, such as deforestation in recharge areas, that accelerate dissolved salt transfer to the surface (Land Development Department, 2009). Soil salinity reaches a steady state when the amount of salt intruding into the soil profile is equaled by the amount leaving the soil surface via stream flow. This phenomenon is widespread in rice paddy fields where salt accumulates easily and gradually deteriorates over time (Barrett-Lennard, 2002). Sayok et al. (1993) reported that soil EC measures for specific clear-cut areas in the Davy Crockett National Forest near Apple Springs, Texas were higher than adjacent, undisturbed forest land.

Economically speaking, rice (*Oryza sativa* L.) is Thailand's most important cash crop. During 2009-2011, Thailand exported about 9.42 million tons of rice annually, estimated at USD 5.18 million per year (Office of Agriculture Economics of Thailand, 2012). In 2011, the total harvested paddies were estimated at 8.91 million ha, of which about 5.55 million ha (62.22%) were from the Northeast (12.01 million tons accounted for 51.60% of Thailand's total rice production). Although the region's total rice production is relatively high, the yield per unit area is only 2.02 tons/ha as compared to the national average yield of 2.38 tons/ha (Office of Agriculture Economics of Thailand, 2012). This is due to several factors, including the region's climatic conditions, poor soil fertility, low inputs (Wijnhoud et al., 2003) and soil salinity (Quantin et al., 2008). Rice yields and economic returns are about one third less in saline soil as compared with nearby unaffected areas (Hall et al., 2004).

Salinity has a harmful impact on soils and crop production. Excessive amounts of salt adversely affect the physical and chemical properties of soil, as well as microbiological processes (Lakhdar et al., 2009). Salinity and sodicity also affect crop yields because of osmotic effects and sodium toxicity (Marschner, 1995). If nutrient up-take efficiency decreases, then plants will suffer. For example, nitrogen deficiency expresses itself in older leaves of rice – those having a pale and dry leaf apex. Prolonged nitrogen deficiency causes severe plant stunting, reduced tillering, and yield reduction. Additionally, increased levels of salt can result in soil compaction, thus reducing water infiltration and causing difficulty in plowing. Wijnhoud et al. (2003) stated that farming decisions often favor rice paddies with higher income potential, thus shifting management priorities to socioeconomic factors. Family income can also affect farm management practices, including fertilizer application.

## OBJECTIVE

Soil salinity tends to increase when vegetative cover decreases. This can exacerbate land limitation problems, especially on rice production which takes place in areas where soil salinity typically occurs. Subsequently, ecological factors, such as the availability of nutrients (N-P-K) can affect rice production. Furthermore, farm management practices (e.g., fertilizer application, manure input and irrigation) play key roles in productivity, but success is heavily dependent upon the farmer's socio-economic condition. This study examined several factors affecting rice production at Nong Due Village, Nong Song Hong district, Khon Kaen province, including the relationship between saline soil distribution and vegetative cover. Better understanding of soil salinity and rice production problems will help farmers to more effectively adapt, thus to a certain extent help improve their productivity and benefits gained.

## METHODOLOGY

Two data collection activities were done. Firstly, soil samples from both saline and non-saline rice paddies were collected in April, 2012 using a composite sampling method for soil property analysis, including ECe, organic matter (titration method, modified from Walkley and Black, 1934), N (calculation derived from OM values), P (Bray no. II method), K (Flam photometry method), soil pH, texture and color. Sampled paddy coordinates and elevations were recorded on a GPS receiver (Garmin etrex). The distance between each sampled plot to the closest forest was estimated using a Google Earth map. Correlations between soil sample ECe values and distances to the closest forest, as well as elevations, were calculated to determine the extent of salinity distribution.

Secondly, a questionnaire was administered to villagers in July, 2012 to measure rice production, farm management practices, and household socioeconomic factors. Most of the quantitative data such as rice yields, nutrient inputs, and residue management were provided by farmers during oral interviews. Units were standardized, which involved conversion of volumes to weights. This conversion was checked through direct observations of rice containers and/or sacks. Descriptive statistics, t-tests and correlations were performed to examine potential factors affecting rice production.

## RESULTS AND DISCUSSION

Nong Due (UTM 48P 263316mE 1733847mN) is a village in Dong Keng sub-district, Nong Song Hong district, Khon Kaen province, Thailand. Patches of soil salinity can be observed in rice paddies, especially during the dry season. Rice paddies were primarily located northeast of the village adjacent to a dry Dipterocarp forest called Kok Nongjan (KNJ) community forest (UTM 48P 265044mE 1735511mN). The southern side of the village was surrounded by a forest patch with trees scattered throughout the rice paddies (Fig.1).


**Fig. 1 Nong Due Village (A): rice paddies and surrounding forests - KNJ (B)**
(*Source: Google Earth, 2012*)

### Soil salinity distribution

A total of 68 soil samples from both saline and non-saline rice paddies were collected. The sampled point elevations ranged from 146 m to 178 m with the lowest estimated soil ECe 0.19 dS/m up to 16.58 dS/m. The average distance from non-saline rice paddies to the closest vegetation was 0.28 ± 0.10 km, while high salinity sampled plots were found farther away from the forests (Table 1). Although soil salinity distribution did not show significant correlations with distance, high salinity areas tended to occur in lower elevations and farther away from vegetative cover.

**Table 1 Salinity distribution: sampled point elevation, distance to the closest forest and ECe**

| Salinity level | ECe (dS/m) | | Elevation (m) | Distance (km) to the closest vegetation | No. of sampled points (%) |
|---|---|---|---|---|---|
| | Criterion * | Range | | | |
| Non saline | <2 | 0.19- 1.99 | 161.95 ± 7.60 | 0.28 ± 0.10 | 41 (60.29) |
| Slightly saline soil | 2-4 | 2.33- 3.83 | 159.89 ± 5.37 | 0.29 ± 0.09 | 9 (13.24) |
| Moderately saline soil | 4-8 | 4.09- 7.49 | 162.43 ± 4.65 | 0.30 ± 0.11 | 7 (10.29) |
| Highly saline soil | 8-16 | 8.49-14.63 | 159.20 ± 5.81 | 0.32 ± 0.12 | 10 (14.71) |
| Severely saline soil | >16 | 16.58 | 161 | 0.30 | 1 (1.47) |

*Source: *U.S. Salinity Laboratory Staff (1954)*

### Soil properties

Soil samples consisted of loamy sand with high variability of pH (3.64-9.93, median=7.28). Takuhito et al. (2006) found that soil pH can be affected by water drainage during fallow periods and rice straw inputs to the soil. Water drainage during the fallow season increases soil pH, which might explain higher pH readings in the sampled plots since it rained the night before sampling occurred. Furthermore, the application of rice straw decreases soil pH, partly due to the decomposition of organic matter. Since organic materials serve as an electron donor for soil reduction, the soil pH decreases because of increased pressure from $CO_2$ (Ponnamperuma et al., 1966; Takuhito et al., 2006).

Soil coloration from the saline samples ranged from reddish yellow to strong brown, while samples from non-saline paddies were reddish yellow to pinkish gray. The majority of soil samples (60.29%) were classified as non-saline, except for one location (Table 1). Furthermore, the majority of soil samples had low nutrient contents (Tabel 2), including OM and N (less than 1%). This finding is typical for soils in Northeast Thailand (Tulaphitak, 2002), partly due to loamy sand texture, erosion, and land use activities. Only a few samples yielded moderate to high contents of K. The independent samples t-tests showed significant differences of OM and total N contents between non-saline soil and saline sites (mean difference = 0.127 and 0.006; p-value < 0.05, respectively). Although no significant difference was detected, available K contents of saline soil samples were higher than non-saline soils (Table 3). This may result from poor nutrient uptake caused by dehydration since the rice plants were growing in saline soil (Patel et al., 2009).

**Table 2 Soil properties: Total OM, Total N, Available P and K**

| Soil salinity | Parameters | Soil fertility | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low* | | Moderate* | | High* | |
| | | Mean ± S.D. | No. of samples (%) | Mean ± S.D. | No. of samples (%) | Mean ± S.D. | No. of samples (%) |
| Non-saline soil | OM (%) | 0.44 ± 0.29 | 41 (100) | - | 0 (0) | - | 0 (0) |
| | N (%) | 0.02 ± 0.01 | 41 (100) | - | 0 (0) | - | 0 (0) |
| | P (ppm) | 0.11 ± 0.05 | 41 (100) | - | 0 (0) | - | 0 (0) |
| | K (ppm) | 28.75±13.69 | 29 (71) | 70.22 ± 12.38 | 8 (20) | 98.43 ± 6.81 | 4 (10) |
| Saline soil | OM (%) | 0.31 ± 0.22 | 27 (100) | - | 0 (0) | - | 0 (0) |
| | N (%) | 0.02 ± 0.01 | 27 (100) | - | 0 (0) | - | 0 (0) |
| | P (ppm) | 0.08 ± 0.08 | 27 (100) | - | 0 (0) | - | 0 (0) |
| | K (ppm) | 19.79±10.87 | 22 (81) | 83.40 ± 0.44 | 3 (11) | 255.55 ± 127.07 | 2 (7) |

*Note: *Standards: Total OM (%): Low <1.5, Moderate 1.5-3.5, High >3.5; Total N (%): Low <0.3, Moderate 0.3-0.6, High >0.6; Available P (ppm): Low <10, Moderate 10-25, High >25; and Available K (ppm): Low <60, Moderate 60-90, High >90*

*Source: Soil Survey Division, Land Development Department (1980)*

**Table 3 Comparison of soil nutrient contents between non-saline and saline soil samples**

| | Group | N | Mean ± S.D. | Mean Difference | t-test (p-value) | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| OM (%) | NS | 41 | 0.437 ± 0.209 | 0.127 | 2.354 (0.022) | 0.021 | 0.233 |
| | SS | 27 | 0.310 ± 0.223 | | | 0.019 | 0.235 |
| N (%) | NS | 41 | 0.022 ± 0.0104 | 0.006 | 2.349 (0.023) | 0.001 | 0.012 |
| | SS | 27 | 0.016 ± 0.0112 | | | 0.001 | 0.012 |
| P (ppm) | NS | 41 | 0.111 ± 0.054 | 0.030 | 1.943 (0.056) | -0.001 | 0.062 |
| | SS | 27 | 0.080 ± 0.075 | | | -0.0031 | 0.064 |
| K (ppm) | NS | 41 | 43.638 ± 27.634 | -0.686 | ns | -24.761 | 23.389 |
| | SS | 27 | 44.324 ± 69.526 | | | -29.343 | 27.970 |

*Note: NS = non-saline soil sample and SS = saline soil sample*

## Rice production and farm management in saline soil farming systems

Rain-fed rice cultivation is the primary occupation of Nong Due villagers. A total of 40 household representatives (out of 70) participated in the survey. A majority of the households (n=34) had encountered soil salinity issues (the averaged size was 0.89 ha/household which accounted for 34% of their total paddy area). Primarily, farmers grow two rice cultivars including a glutinous mutant of jasmine rice—RD6 and jasmine rice—KDLM-105. The average rice yield from farmers who experienced soil salinity was 1.9 tons/ha, lower than the average production from non-saline paddies (mean difference –113.39 kg/ha). Moreover, the size of saline paddies showed a negative correlation with rice production ($R^2$ = 0.120, p-value = 0.029).

The average household annual income derived from a four-person labor force was approximately 112,000 Baht (USD1 ~ 30.64 Baht as of December 14, 2012). These figures were not significantly different between households that experienced soil salinity and those who did not. Moreover, the household income and labor force did not show significant correlations with farm management practices. Fertilizer application is likely dependent upon the availability of on-farm resources and word-of-mouth. Nonetheless, the total paddy field per household significantly correlated with rice yields ($R^2$ = 0.275, p-value = 0.001). Although this finding implies that the labor force may not differ across samples, it does limit household production and management abilities.

Rice production costs of farming systems which experienced soil salinity were estimated at 10,770 Baht/ha. The highest spending was associated with farm maintenance, especially from farmers using chemical fertilizers. The costs from non-saline farming locations were 9,791 Baht/ha, with 39.75% also spent on farm maintenance (Table 4). Seemingly, farmers have adapted to soil salinity by using on-farm resources, such as cow manure, compost, and green manure. Farmers also raised the height of paddy borders, so that more rainwater could be stored, thus ensuring that the rice paddies were continuously submerged. Clermont-Dauphin et al. (2010) reported that approximately 20% of rice yields decreased because of salinity, but 87% decreased due to drought. Therefore, water management is very important for rice cultivation, especially in saline paddies.

**Table 4 Rice production and farm management information of sampled households**

| Information | Households without saline paddies (6 households) | Households with saline paddies (34 households) |
|---|---|---|
| 1) Averaged size of total paddies (ha/household) | 2.74 | 2.63 |
| 2) Averaged size of saline paddies (ha/household) | - | 0.89 |
| 3) Household's total rice production (tons/ha) | 2.0 | 1.9 |
| 4) Income (Baht/household) | 133,000 | 108,000 |
| 5) Labor force (persons/household) | 4.06 | 3.50 |
| 6) Total costs of rice production (Baht/ha) | 9,791 | 10,770 |
| 6.1) Land preparation and rice growing (transplanting and sowing) | 3,095 (31.61%) | 2,618 (24.31%) |
| 6.2) Maintenance costs | 3,892 (39.75%) | 4,771 (44.30%) |
| 6.2.1) Chemical fertilizer application | 3,022 (77.64%) | 2,775 (38.15%) |
| 6.2.2) Manure application | 548 (14.07%) | 451 (9.46%) |
| 6.2.3) Pesticide application | - | 64 (1.35%) |
| 6.2.4) Organic fertilizer application | - | 1,294 (27.11%) |
| 6.2.5) Rice husk & mulch application | 323 (8.29%) | 187 (3.93%) |
| 6.3) Harvesting costs | 2,804 (28.63%) | 3,381 (31.39%) |

*Note: USD1 ~30.64 Baht as of December 14, 2012.*

## CONCLUSION

Soil salinity is a prolonged issue for many farmers in Northeastern Thailand. Its distribution is likely to expand if deforestation in recharge areas continues to occur. Despite the low correlation between soil ECe and distance from saline plots to the closest vegetation, high salinity frequently occurs in lower elevations and areas farther away from forest cover. Approximately 34% of the rice paddies with soil salinity issues also encountered low soil nutrients. The average rice yield of farmers experiencing soil salinity is lower than the productivity from non-saline paddies. This finding illustrates that soil salinity negatively affects rice production. However, household income and labor force did not show significant correlations with farm management practices. Fertilizer application is likely dependent on available on-farm resources and word-of-mouth. As long as soil salinity remains an issue, then farmers will be forced to adapt. Use of on-farm resources, such as cow manure, compost, and green manure are environmentally sensitive ways to reduce soil salinity. Another effective strategy is raising the height of paddy borders, so that rainwater capture can continuously submerge the rice paddies.

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