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Spatial Variability in Maize Productivity in Uplands of Northwest Vietnam

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Introduction

In mountainous regions of Northwest Vietnam, agriculture is the main source of income for its population. The long term development of Vietnamese agriculture, however, depends on the efficient and effective use of land, and on the adoption of policies in relation to land, land markets and associated inputs and resources (Gordon et al., 2006). Annual cash crops such as maize and cassava are grown on upland fields whereas paddy rice is found in the bottom of the valley (Kono and Rambo, 2004). Over the past decades, maize has got more and more important through a better world market price associated with a hype for biofuels and is now a main cash crop for farmers (Valentin et al., 2008). Current production systems of maize and cassava make fields prone to erosion as the soil cover by both crops is rather poor during juvenile growth (Pansak et al, 2008; Leihner et al, 1996). Soil loss by erosion leads to a spatial variability of crop performance due to an unequal decrease in soil fertility. Large field-to-field variability has been observed in Northern Vietnam in terms of crops, cropping practices, fertilizer use and soil fertility status. Furthermore there has been a more permanent variability in soil properties in relation to parent material affecting soil development and nutrient status. There is still more research on spatial variability needed to improve current recommendations under development. Especially if the recommendations relay on existing soil maps, which are often very old and soil classifications were not developed for agronomic purposes (Witt, 2007). Through economic pressure farmers had to start cultivate fields on steep terrain and further away from their homesteads. The focal point of this study was to understand the impact of field distance to homestead and cropping history on spatial variability in plant development and yield.

Material and Methods

This study was conducted in 2008 in an intensively cultivated subcatchment within the Chieng Khoi Commune, Yen Chau District, Son La province, Northwest Vietnam. The Yen Chau district has a yearly maximum temperature of 38°C and a minimum temperature of 7°C, with a rainfall amount of around 1,220 mm year^{-1} falling from April to October. The geology of the study area mainly consists out of silt-fine sandstone but also Lixisols with calcareous clay-silt stone as parent material have been found.

Three fields were selected according to distances to the homesteads, cropped with the maize (*Zea mays L.)* variety CP888. Field 1 was intercropped with cassava (*Manihot esculenta* Crantz.) while Fields 2 and 3 had a maize monocrop. On the upper, middle and lower slope position of each

field three monitoring plots of 3x5m were delineated. In each of these plots crop density, height, growth stage and yield were determined. A pair wise comparison of maize yields was carried out with a t-test to identify significant differences ($P \leq 0.05$) between two slope positions.
Leaf area index (LAI) was assessed with a LAI2000 canopy analyser (Licor, USA). This device also provides information on the light transmission rate (LTR), a parameter indirectly indicating ground cover. A chlorophyll metre (SPAD-502, Konica-Minolta, Germany) was used to assess the leaf nitrogen status by greenness of leaves during crop growth. SPAD (Soil Plant Analyses Development) measures the nitrogen-status of the plant in a non-destructive way. Crop development was assessed at four stages during the cropping period (50, 65, 92 and 110 days after planting, DAP).
Field characteristics and crop management by the local farmers were monitored and evaluated (Tab. 1). To quantify erosion and runoff rates of each field, three Gerlach troughs (Gerlach, 1967) were installed on the same slope positions containing the monitoring plots for crop development in each field. Soil samples were collected at all field in each slope position and analysed using standard methods. Preliminary evaluation indicates that pH values varied among fields (Tab. 2). Field 3 had higher pH values than the other two fields. A similar variability was observed for available P, with highest values in Field 2 and lowest in Field 1. Field 3 with the youngest cropping history had clearly the best pH values whereas Field 1 with the longest cropping history had the lowest pH and $P_{avail.}$ values. Analysis of soil parameters such as texture, total N, total C is pending.

Tab.1. Characteristics and crop management of monitored fields in the Chieng Khoi watershed, Son La province, NW Vietnam.

Distance to homestead	Field 1 (F1) 0 m	Field 2 (F2) 500 m	Field 3 (F3) 1000 m
Cropping history	>30yr of cultivation Since 2005 maize-cassava cultivation	maize cultivation since 1999	maize cultivation since 2004
Planting date	March 30th	March 30th	March 30th
Field practices	Ploughing: twice Weeding: once	Ploughing: twice Weeding: once	Ploughing: twice Weeding: once
Fertilization	50kg N/ha, 100kg P/ha, 30kg K/ha Urea: 368 kg N /ha	33.5kg N/ha, 67kg P/ha, 20.1kg K/ha	25kg N/ha, 50kg P/ha, 15kg K/ha Urea: 236 kg N /ha
Field size	1000m^2	1500m^2	1000m^2
Maize variety	CP888	CP888	CP888
Plant density	2.7 plants/m^2	3.8 plants/m^2	4.2 plants/m^2

Tab.2. pH and $P_{avail.}$ in the topsoil of three monitored fields in the Chieng Khoi watershed, NW Vietnam as affected by slope position and field distance from homestead (F1: 0 m ; F2: 500 m; F3: 1000 m).

	Field 1			Field 2			Field 3		
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
pH ($CaCl_2$)	4.2	4.4	4.7	4.5	4.1	5.3	5.4	6.3	6.9
$P_{avail.}$ (mg/kg)	1.37	1.54	1.12	4.12	4.12	4.21	2.7	3.7	3.3

Results and Discussion

At 55 days after planting (DAP), SPAD measurements showed values slightly below 50 in all fields (Fig. 1). Thereafter values started to decrease but showed different patterns among fields and slope positions, especially in Fields 1 and 2. Values decreased in Fields 1 and 2 to 35 and 45 at 64 DAP values, whereas in Field 3 values higher than 45 were still observed. Largest difference was observed in Field 2 with SPAD values of 24 on the lower and 39 on the upper position. At 110 DAP, only Field 3 had still values above 35 in each position. Differences between slope positions were smaller in Field 3.

LAI development was different between fields and across slope position within a field (Fig. 1). Field 2 showed a very good crop development on the lower position at 55 DAP. This is attributed to a better nutrient status, represented by a higher $P_{avail.}$ value at this position. Thereafter, plant development in this slope position was depressed by heavy lodging so that the middle and upper position reached similar yields at harvest (Tab. 3). At 110 DAP, however, larger differences were only observed in Fields 1 and 3 where the lower and the middle position, respectively, were clearly superior compared to the other positions within a field.
The highest ground cover was found in the lower position of Field 2, but with strong differences compared to the other two slope positions at 55 and 65 DAP (Fig. 1). Again, differences in $P_{avail.}$ can be the reason. Almost no or no differences were observed between slope positions in both other fields. Ground cover development, however, was faster in all positions of Field 3 with the youngest cropping history, but did not exceed 80% during the entire cropping season.

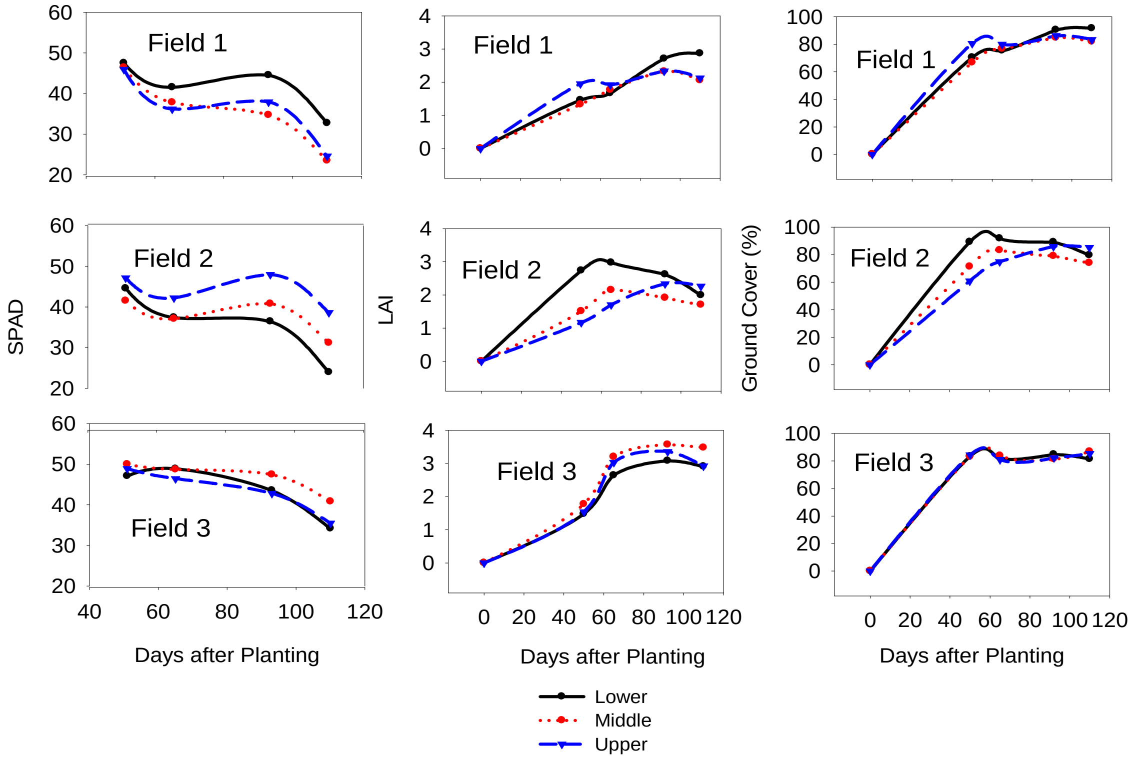

Fig.1. Development of SPAD, LAI and ground cover at three monitored fields in the Chieng Khoi watershed, NW Vietnam as affected by slope position and field distance from homestead (F1: 0 m ; F2: 500 m; F3: 1000 m).

Variability in maize grain yields is presented in Table 3. Field 3 had a much higher yield level compared to Fields 1 and 2. Across slope, no significant yield differences were observed in Field 3 whereas significant differences between upper and middle or lower positions were found in Fields 1 and 2, resulting from the heterogeneous crop development in both fields. Field 3 with a grain yield of more than 10 t/ha maize production had a yield twice as high as that of Fields 1 and 2. This was mainly influenced by a higher planting density in this field as fields with a younger cropping history sustain a higher planting density. Field 1, however, was heavily fertilised and did not reach the yield level of Field 3 anymore, indicating that the soil is already degraded.

Highest soil loss was observed in Field 3 on the lower position with almost 70 t/ha and in Field 2 on the middle position with more than 60 t/ha, whereas soil loss of Field 1 did not even reach 1 t/ha soil loss during the entire cropping period (Tab. 4). Field 1 has probably already lost most of its topsoil as result of over 30 years of crop production (Tab.1). Driving forces for the soil loss were two heavy rainfall events at the beginning of the cropping season.

Tab.3. Maize grain yields (t/ha) of three monitored fields in the Chieng Khoi watershed, NW Vietnam as affected by slope position and field distance from homestead (F1: 0 m ; F2: 500 m; F3: 1000 m).

Slope Position	Field 1 (t/ha)	Field 2 (t/ha)	Field 3 (t/ha)
Lower	5.3[b*]	4.7[b]	9.7[a]
Middle	4.1[b]	4.7[b]	10.5[a]
Upper	6.2[a]	6.6[a]	11.4[a]

* Figures within a column followed with the same letter do not differ significantly at $P<0.05$, using t-test

Tab.4. Soil Erosion (kg/m²) measured by Gerlach troughs as affected by slope position and field distance from homestead (F1: 0 m ; F2: 500 m; F3: 1000 m).

Soil Erosion	Lower	Middle	Upper
Field 1 (kg/m²)	0.001	0.004	0.002
Field 2 (kg/m²)	0.078	6.190	0.169
Field 3 (kg/m²)	6.853	0.283	0.012

Conclusion

Fields with longer distance to homestead have a more recent cropping history and have, therefore, a higher yield potential than fields closer to the homestead which were already cultivated for longer periods.

Plant development within the cropping period showed spatial variability across the slope and between fields. Field 3, the field with youngest cropping history, had by far the highest yields, the most homogenous plant development within the slope with regard to LAI and SPAD. Higher variability in grain yields across slope position was found in fields with long-term cropping history.

Results of soil loss showed the importance of erosion. Fields with young cropping history have still a high potential for obtaining good yields as soil parameters are still good. But through intensive rainfall and cropping on steep slopes, fields will lose their fertile topsoil which in turn will decrease their yield potential in the course of time.

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