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A study on the productivity under the continuous maize cultivation in Sainyabuli Province, Laos I. Yield trend under continuous maize cultivation

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ABSTRACT

Continuous maize cropping has increased in Laos. Because maize is continuously cultivated without fertilizer or any soil conservation practices, there is a concern that maize yield is decreasing. In this study, we conducted a field survey and interviews with farmers to quantify maize production sustainability under continuous cultivation in relation to topographical characteristics in farmers' fields within Sainyabuli Province, Laos. Yield was investigated over a two-year period at three sample sites in each of the 40 farmers' fields, including sloped and flat fields. In addition, to analyze the difference in yield trend due to topo-sequential position, the sample sites were categorized into four topo-sequential positions per slope angle and relative elevation: "upper," "middle," and "lower" positions for sloped fields and "flat" for flat fields. The period of continuous maize cultivation in each field varied from 1 to 30 years. The average yield of the three sample sites in each field varied from 1.1 to 6.0 t ha^{-1} and tended to be lower as the period of continuous cultivation was longer. ANCOVA and regression analysis for each topo-sequential position indicated that the decreasing yield trend in each field were mainly derived from the upper position of sloped fields. Cost of 1.7 t ha^{-1}, in terms of maize yield, were required for purchasing seed, herbicide, and outsourcing plowing in maize cultivation. The linear regression line of the yield based on the period of continuous cultivation suggested that maize production decreased at −0.06 t ha^{-1} $year^{-1}$; but it could be economically viable for 43 years. However, yield in six of the 36 fields was evaluated as below profitable levels, indicating that urgent improvements in field and crop management are required to produce maize sustainably.

1. Introduction

Increasing population and the pursuit of cash incomes have intensified crop cultivation in upland fields of Southeast Asia. The area of continuous crop cultivation has increased while the area of traditional shifting cultivation has decreased (Thongmanivong and Fujita, 2006; Vliet et al., 2012). Notably, in Laos, the harvested area for maize increased from 44,956 ha in 2002–214,460 ha in 2014. Maize became one of the major cash crops in Laos and is primarily produced in the northern mountainous areas. Kenthao District in Sainyabuli Province is the one of leading districts for maize production, where the continuous cultivation has been conducted for over 30 years.

In general, soil is easily degraded in tropical zones. High rainfall intensity is frequently observed during the rainy season, which increases erosion and causes rapid soil degradation (Wischmeier and Smith, 1958). High temperature also increases the rate of decomposition of soil organic matter (Raich and Schlesinger, 1992). Accordingly, rapid decreases in maize yield have been commonly anticipated in the tropical zone. Anthony et al. (1995) reported that yields decreased by 4.5 t ha^{-1} over nine years from a fertilization experiment in Nigeria. Sileshi and Mafongoya (2006) reported that yields decreased by 2.0 t ha^{-1} over four years from an experiment in Zambia. Moebius-Clune et al. (2011) assessed yield from several farmers' fields in Kenya, and estimated that yield decreased about by 2 t ha^{-1} over 12 years. On the contrary, over 30 years of maize production in Laos seems not to follow the above examples, although maize was commonly cultivated via continuous cropping without any external input of fertilizer or soil conservation practices. The evaluation of sustainability in maize production is quite important to forecast future production in the country and in places where maize production is introduced, instead of shifting cultivation. However, to our knowledge, scientific study regarding maize production in farmers' fields in Laos is quite limited.

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Scientifically, long-term trends of soil condition and crop yields are often analyzed by chronosequence methods, which compare target variables among discrete fields with various periods under cultivation managements (Kiyono et al., 2007; Moebius-Clune et al., 2011; Nyberg et al., 2012). Nyberg et al. (2012) conducted a field investigation at eight Kenyan sites with various maize cultivation periods to evaluate soil property trends under crop cultivation that had been operating for 120 years, and concluded C and N concentrations in soil dropped to around 60% from the initial values. Similarly, Moebius-Clune et al. (2011) conducted research in several farmers' fields to evaluate trends in soil conditions and maize yield in Kenyan fields over 80 years, and reported yield decrease of 2 t ha^{-1} over 12 years.

Crop yield is generally different based on topo-sequential positions. Yield is better at lower positions than upper positions on a slope field (Miller et al., 1988; Verity and Anderson, 1990). This yield difference is due to the redistribution of soil from erosion and sedimentation during crop cultivation. Because maize production in northern Laos is primarily conducted on sloping land, the effect of soil erosion and sedimentation should be large. Given the topographical characteristics, differences in yield trends due to topo-sequential positions need to be evaluated.

The objective of this study is to evaluate maize productivity and soil fertility under continuous maize cultivation in farmers' fields in Sainyabuli Province. To achieve this objective, we selected farmers' fields with varying periods of continuous maize cultivation and different topo-sequential positions. This first report showed the maize yield trend in relation to topo-sequential positions under continuous cultivation, and it discussed production sustainability in terms of yield trend and economical balance assessment.

2. Methodology and measurement

Research was conducted in Sainyabuli Province, located in a northern mountainous area (Fig. 1), where most farmers' fields lay on sloping land. The average annual precipitation in Saynyabuli province is 1362 mm, of which 77% is recorded in the rainy season (i.e., May to September). Because the precipitation in the dry season is inadequate, most farmers plant one crop per one year only in the rainy season. The average temperature in the rainy season is 27.5 °C.

In Kenthao District of Sainyabuli Province, maize cultivation was introduced 30 years ago. The period of continuous maize cropping varied from 1 to 30 years among fields, depending on reclamation time, when the fields were converted from primeval or secondary forest. During continuous cropping, only maize is cultivated in the rainy season; no crops were cultivated in dry season; and only one planting was harvested annually. Hybrid varieties of Charoen Pokphand Seeds Co. Ltd. were used in most farmer's fields. Sowing was conducted in the period between May and June, after tillage. Grain and cobs were harvested between September and November, with the stems and leaves left on the fields. No fertilizers or fallowing was conducted. These cultivation management methods were common to all farms investigated in this study. Soils in the study area are categorized into Acrisol, in the soil map of FAO taxonomy (1976), and Ultisol, in the global soil regions map of USDA taxonomy (2005).

In 2014 and 2015, 21 and 19 fields were respectively investigated in two villages (Fig. 1). Field size vary from 0.3 ha to 2 ha, and 0.9 ha in average. Three sample sites were selected to equally distribute the slope with maximum angle for each field, and were categorized into four topo-sequential positions: upper, middle, lower, and flat positions, to evaluate the effect of geographical characteristics on yield trend under continuous cultivation. The categorization first defines fields into two types: sloped (i.e., slope angles over 8°) and flat fields. The slope angle of the field was determined from the position information of three sample sites measured with a global positioning system, and from calculation using QGIS with data from Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model, ver. 2 (ASTER GDEM ver. 2; NASA, 2011). Next, sample sites of sloped fields were categorized into upper, middle, or lower positions per the relative elevation of three sample sites at each field; the three sample sites of each flat field were categorized into flat positions.

Yield was quantified during the crop maturity season in September and October. Grain was collected from 3 × 3 m plots from where the

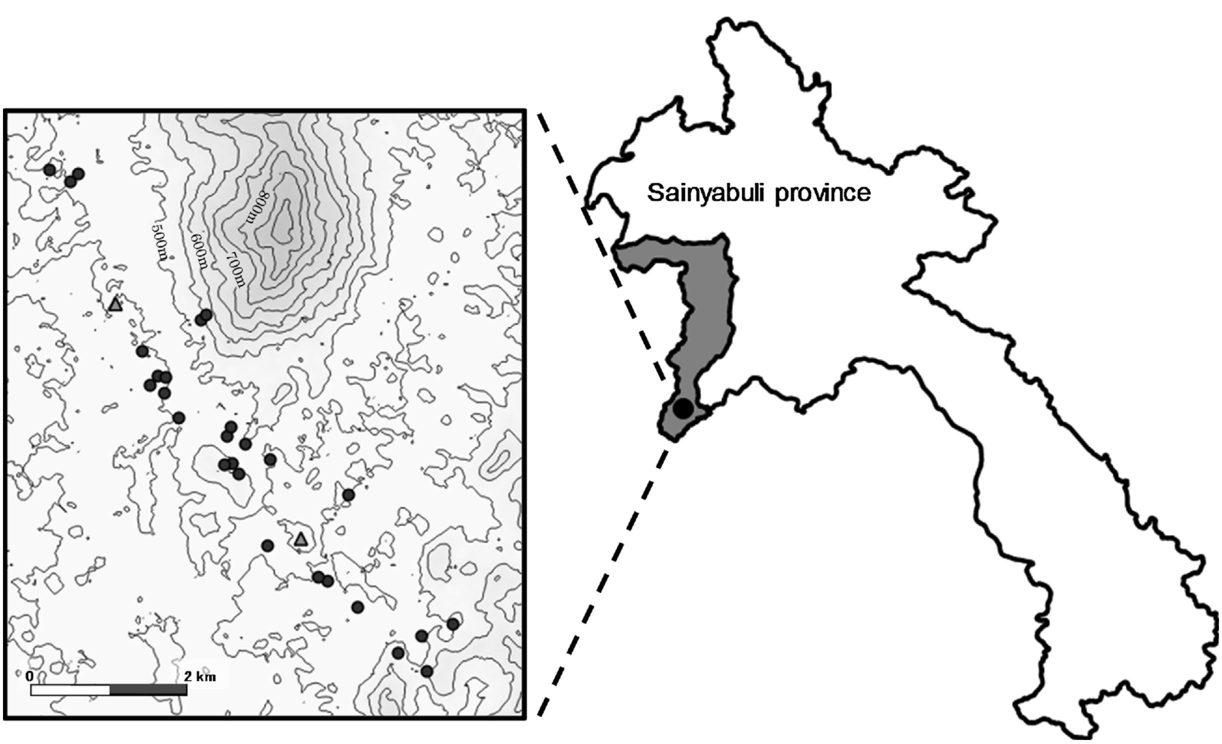

Fig. 1. Map of the study area, including the investigated fields and villages in Sainyabuli Province. The closed circle symbols represent the investigated maize fields. The triangle symbols represent villages.