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Short communication

Effect of altitude and slope on radiation absorption, growth and yield of *jhum*-land rice at Ri-Bhoi district of Meghalaya

U.S. SAIKIA*, R. KRISHNAPPA, B. GOSWAMI, SANTANU DAS, A. KUMAR, E. SHYLLA, M. LYNGDOH, and S.V. NGACHAN

ICAR Research Complex for NEH Region, Umroi Road, Umiam 793 103, Meghalaya

**Corresponding author: ussaikia73@gmail.com*

Shifting cultivation or *jhum* is the dominant land-use practice of the hilly part of the North Eastern (NE)region of India. *Jhuming*, in its more traditional and cultural integrated form, is an ecological and economically viable system of agriculture as long as population densities were low and *jhum* cycles were long enough to maintain soil fertility (Anonymous, 1992). Presently, it is estimated that the number of people practicing shifting cultivation are around 367,000 tribal families in the NE India and the area affected by this practice is 385,400 ha annually (Patiram and Verma, 2001). On an average, an area of 3,869 km^2 is put under shifting cultivation every year. Though *jhum* has been recognized with many faults and drawbacks, the International Center for Integrated Mountain Development (ICIMOD) recognized *jhum* cultivation as a good practice in terms of farming, forestry, soil and water conservation and bio-diversity management (Kerkhoff and Sharma, 2006). In spite of persistent efforts made by the government and NGOs, the *jhuming* practices of tribal people of the region could not be effectively eradicated through introduction of improved technologies. This may be attributed to involvement of several complicated factors like socio-economic, geographical and techno-political angles etc. Due to lack of any other viable way of livelihood, now policies have got a paradigm shift from *jhum* eradication to *jhum* improvement, which is likely to ensure increased level of sustainability.

The major crops grown in *jhum* lands are rice, maize, millets, sesame, cotton, ginger, cucumber, pumpkin, bottle gourd, mellon etc. in a mixed cropping pattern till the soil lost its viability. The abandoned *jhum* fallow area rejuvenates into secondary forest from copies, underground rhizomes, root and suckers and the soil seed bank in varying span of time (Mantel *et al.,* 2006).In traditional *jhum*, the crops utilize natural resources, including solar radiation, not exactly the way crops grown in the flat valley lands. It may be attributed to several factors like mixed cropping, variation in soil moisture, temperature and shading effects by virtue of variation in altitude, slope and exposure to solar radiation, which ultimately affects the crop growth and development. In modern agriculture, there is immense need of study of the micro-climate of any crop and relationships between micro-climatic variables and crop growth and development parameters to meet the knowledge gap in optimizing location specific agronomic practices and selection of suitable crop/ cultivars. Though these information are readily available in case of settled agriculture but very rare in case of shifting agriculture practiced in sloppy lands. Hence, this study was taken up with respect to upland rice cultivated in *jhum* lands to characterize the micro-climate and affects of micro-climate on realization of economic yield.

This study was conducted in Umeit village of Ri-Bhoi district of Meghalaya during 2014-2015 (25°41'N; 91°63' E; altitude is 980 m above mean sea level). A three dimensional digital elevation model (DEM) of the experimental area has been presented in Fig. 1. The climatic condition of the region is subtropical hot and humid. It receives an average annual rainfall of 2439 mm with a high degree of temporal and spatial variation.The average maximum temperature recorded during rice growing season is 26°C. The experimental plot has average elevation of 914, 913 and 912 m above mean sea level (msl) at top, middle and bottom, respectively, with average slopes of 23.6, 23.4 and 34.6%, respectively, in the same order. The field was exposed to the south west (SW) direction. Upland high yielding rice cultivar Bhalum-3 was direct seeded in lines in the 2nd week of June and harvested in the 3rd week of October. Only external input provided to the soil was FYM @ 5 t ha^{-1}, applied one day before sowing. Observations were taken for maximum leaf area index (LAI), absorption pattern of photosynthetically active radiation (PAR) at flowering stage, grain, straw and total biological yield; and their variation with respect to altitude and slope have been analyzed in Randomized Block Design (RBD).Three plots were made in each level of altitude across

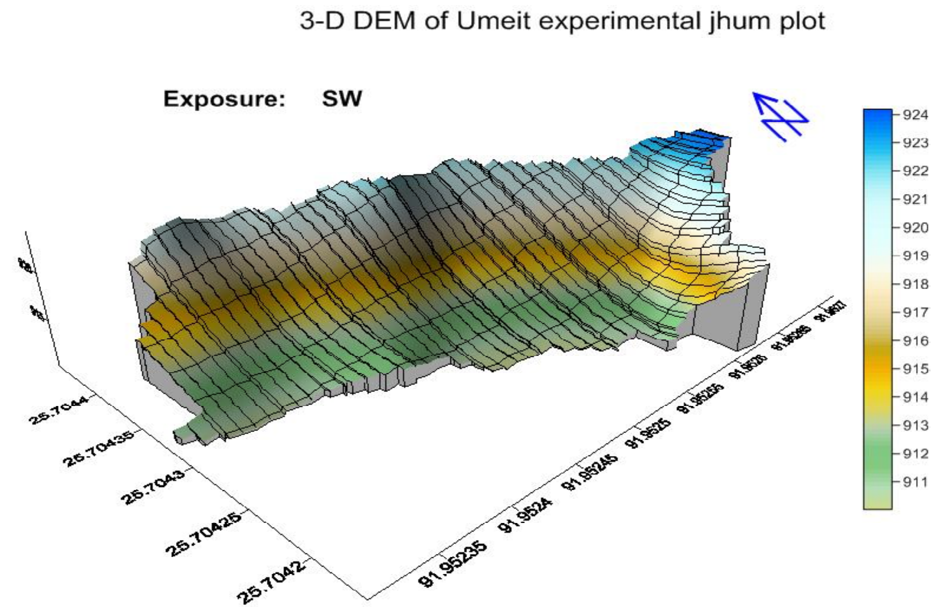

Fig. 1 : 3-D Digital elevation model of the study area

Table 1: pH and nutrient status of soil (0-15 cm) before sowing and after harvesting of the crop

Parameters	Before sowing (range)	After harvest		
		Top of the field	Middle of the field	Bottom of the field
pH	4-4.5 (4.4)	4.5	4.5	4.3
Organic carbon (%)	0.7-3.6 (1.9)	1.7	2.6	1.4
Avail N (kg ha^{-1})	100-250 (157.5)	125.4	121.3	225.8
Avail. P (kg ha^{-1})	4-10 (6.4)	6.9	6.1	6.3
Avail. K (kg ha^{-1})	204-306 (280.1)	248.6	319.2	272.6

Values in brackets are average value of the parameter

Table 2: LAI, absorbed PAR and soil moisture content at the flowering stageand yield of rice at different levels of altitude and slope

Altitude (m), Slope (%)	Soil moisture(%/V)	LAI	Absorbed PAR (%)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Top (914, 23.6)	25.4b	1.47a	66.8c	2.5c	2.8b	5.3b
Middle (913, 23.4)	30.6a	1.99a	84.3a	4.2a	3.8a	8.0a
Bottom (912, 34.6)	28.8ab	1.73a	74.2b	3.5b	2.4b	5.9b
C.V. (%)	6.9	13.4	2.8	4.9	7.1	4.2
S.E.M.	1.1	0.13	1.2	9.62	0.12	0.16
LSD ($p<0.05$)	4.4	0.53	4.7	0.38	0.49	0.61

the slope and divided by grass water ways for safe passage of rain water. In each plot three nos. of replicated data was collected for every parameter. Further, analysis was carried out to study the influence of plant absorbed PAR and LAI on grain and straw yield of rice. Duncan's multiple range test (DMRT) was carried out to test the level of significance of the outputs.

Result obtained from the study indicated that different altitude and slopes have influenced the soil nutrient status, maximum LAI, Absorbed PAR (%) and yield of rice. The pH and nutrient status of soil (0-15 cm) before sowing and after harvesting of the crop have been presented at Table 1. The middle part of the field exhibited higher values of organic carbon and available K, where as pH and available P were at par with the other two levels of the field. This might be due to lower degree of slope in the middle level compared to other two. Among different nutrients, the change in levels of available N was noticeable. The change might have occurred due to plant uptake of nutrients or washing out down the slope. The top and middle parts of the field had

Table 3: Regression equations to estimate grain yield based on maximum LAI and absorbed PAR in the flowering stage of rice at different levels of altitude and slope

Altitude (m), Slope (%)	Relationships	R^2(d.f=n-2=7)
Top (914, 23.6)	Grain yield = -0.411 + 1.118 LAI+0.225APAR	0.96**
Middle (913, 23.4)	Grain yield = -0.68 + 1.784 LAI+0.221APAR	0.65
Bottom (912, 34.6)	Grain yield = -1.923 + 1.223 LAI+0.614APAR	0.86**

lost available N by an average 34 kg ha^{-1}, where as the bottom portion gained 68 kg ha^{-1} compared to the available N level before sowing.

With respect to influence of different altitude and slopes,the soil moisture content was found significantly higher in the middle level (30.6 %/v) compared to top the top (25.4 %/v), but at par with the bottom level (28.8 %/v).No significant influence of altitude and slope was foundon maximum LAI (Table 2). The middle portion of the field recorded highest value of maximum LAI (1.99), followed by bottom (1.73) and top (1.47) portions.In response to the LAI values, PAR absorption was found highest in middle portion (84.3%), followed bybottom (74.2%) and top (66.8%). Higher availability of soil moisture might have led to higher LAI in the middle and bottom portions of the field that resulted in higher PAR absorption by the plants. Though LAI did not differ significantly, irrespective of slope and altitudes, but the radiation absorption was significantly influenced by the LAI at 5% level of significance.

The LAI is always one of the most important yield defining parameters, which influenced the radiation absorption and there by grain, straw and total biological yields. Significantly higher grain (4.2 t ha^{-1}), straw (3.8 t ha^{-1}) and total biological yields (8.0 t ha^{-1}) were recorded at middle portion of the field, which is at an altitude of 913 m above msl with an average slope of 23.4%. Regression equations were developed between maximum LAI and absorbed PAR (independent variables) with grain yield (dependent variable). It has been done for three different levels of altitude and slope and are as given below:

The equations suggests significant ($P<0.01$) relationships among the parameters. This is further asserting the positive relationships of the parameters as found and presented in earlier part of the discussion.

The findings presented above are the outcome of only one year data and hence, less than conclusive. But it still gives some insight, how altitude and slope influences nutrient dynamics in soil, utilization of solar radiation and crop growth and development. Though it is generally advised that cropping should not be done above 15% slope to avoid excessive soil erosion, but in absence of viable alternative people are practicing agriculture in much higher slopes, say 23 to 34%, in this present case. Hence, to draw maximum sustainable benefit out of the available natural resources we need to know the crop response under different levels slope and altitude, particularly in high rainfall *jhum-lands* of the region. The outcomes are likely to contribute to the cause of overall *jhum* improvement program.

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