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Land Use Planning Using Geospatial Technology and Soil Health Card Data for A Micro Watershed in Sub Tropical Humid Region of Meghalaya

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Abstract

Land use planning based on soil, slope, existing land use land cover and knowledge of the ecology and socio- economy was done for micro watershed 3B2A1d2d of Digaru watershed located in Meghalaya. High resolution Google image was used to prepare present land use land cover map. Areas suitable for rice, maize and pineapple were identified using geospatial technology based on land evaluation using information on soil, slope, rainfall and temperature and requirements of crops. Alternate land use plan was prepared based on crop suitability and existing land user. The study reveals that soils are high in organic carbon and nitrogen, moderately acidic in reaction and medium in phosphorus and potassium. Soils are sufficient in iron and copper. Zinc and manganese is deficient in 21.88% and 3.92% area. Crop suitability analysis reveals that only 57 ha area is suitable for rice and 144 ha area is suitable for maize and pineapple. Based on crop suitability, low lying areas are suggested for rice and maize and pineapple is suggested on uplands. Areas not suitable for any crop are suggested for afforestation.

Keywords: Geospatial tools; Soil fertility; Crop suitability; Meghalaya

Introduction

Use of land according to its capability is the first step towards sustainability. The knowledge of extent of land utilization is essential for any land use planning. Inappropriate land use leads to inefficient exploitation of natural resources, degradation and destruction of the land resources which causes poverty and other social problems. Thus, for sustainable development, optimal utilization of natural resources based on their potential and limitations is essential. This necessitates land use planning, in order to realize the short and long-term benefits, setting of priorities and satisfy the diverse needs of society while at the same time conserving fragile ecosystems and our genetic heritage.

Soil information is a vital component in the planning process, reflecting directly upon land use suitability [1]. Geographic Information Systems (GIS) have contributed to the speed and efficiency of overall planning process. Quick and efficient access to large amount of information is enabled by GIS, exhibiting relationships, patterns, and trends that are useful in combining soil survey information to monitor land use changes. Soil is an important natural resource of which the productive potential is limited by its intrinsic characteristics which can be find out from soil resource inventory. The soil resource inventory for any area provides information of various attributes such as texture, depth, slope, erosion, extent of acidity and salinity, soil drainage, etc. required for any natural resource development programme [2]. Of late, advanced land evaluation techniques using GIS have been found useful in addressing soil fertility constraints and management problems in the areas of low productivity. The lands resources can be better managed through systematic land characterization and evaluating their potentials and limitations with appropriate interventions. Information on existing land use, slope, soils, groundwater availability, rainfall, irrigation facilities and socio-economic conditions of the farmers are necessary to prepare alternate land use plan. Practices like agro-forestry, silviculture, silvipasture, etc. in suitable location based on capability are found to be effective against degradation of land [3].

The geo-spatial technology of satellite remote sensing (RS) coupled with geographical information system (GIS) and Global

Positioning System (GPS) provides a powerful tool, not only to monitor natural resources in terms of relevant, reliable and timely information and environmental changes but also permits to study and analyse the information of other environmental variables [4,5]. A number of studies, carried out worldwide, demonstrate the capability of remote sensing and GIS in development planning [6,7,8,9]. The RS and GIS give a quicker and cost effective analysis for various applications with accuracy for planning and also give a better perspective for understanding the problems and therefore helps planner to evolve a better solution for sustainable development [10,11]. Spatial analysis is vital to economic performance and GIS is important for planning from local to global scales [12,13]. Das et al. [14] have demonstrated the method for land use diversification plan for a cluster of village using remotely sensed data and GIS.

Meghalaya is mainly based on rural economy. About 81% of the state's population resides in rural areas and their livelihood depends on agriculture. Agricultural developmental activities of the state control employment and income generation to a great extent. Therefore, agriculture plays a predominant role in the state's economy. However, the state is yet to reach the national level both in economic and agricultural growth rate. Though 81% of the state's population depends on agriculture, the net cropped area is quite less and is only about 9.87% of the total geographical area of the state. It is necessary to develop an alternate land use plan considering potentials and limitation of natural resources. Therefore, the present study has been taken up to create a comprehensive database of natural resources using geospatial technologies and to generate environmentally and socio-economically sound and sustainable land resources development action plans.

Study area

The study area is a micro watershed 3B2A1d2d situated on the left bank Brahmaputra basin falling under Digaru watershed. The micro watershed lies between 25º54'17.7'' to 25º54'15.4'' N latitude and 91º52'54.7'' to 91º52'66.3'' E longitude and covers an area of 265 ha (Figure1). The study area falls within 17.1 agro ecological sub region zone of sub tropical region with average annual maximum and minimum temperature is 27.6 0C and 17.30C respectively. December is the coldest month with an average minimum and maximum temperature of 7.6 °C and 20.4 °C, respectively. The study area has annual relative humidity of 39.1% with mean annual rainfall of about 2253 mm, 77% of which is received during July to September [15]. The study area is situated on dissected plateau developed on sedimentary and metamorphic rocks. It covers 6 villages viz., Umbuda, Mawroh Mawspeng, Mawroh Mawsyntiew, Mawroh-2, Mawroh Nongmadan, Iewmulong. 73.3 % of the population is under farming community out of which 50% cultivated in their own land and remaining population cultivated on leased land. 83.33% of the population engaged in livestock. High illiteracy rate and low annual income is the main problem of the study area. The geology is extensively covered by porphyritic granite which is intruded into older gneisses with being major minerals predominating in the areas are quartz, K-feldspar, and plagioclase, biotite with accessory apatite, sphene, and zircon. The soils of the study areas are developed on intermontane valley and moderately dissected denudational hills. Soils are deep, well drained to moderately well drained, fine to coarse loamy in texture with low CEC, low to medium base saturation in hyperthermic temperature regime with udic and aquic soil moisture regimes in hills and valley respectively. Inceptisols are the most dominant soil order followed by Entisols and Alfisols [16].

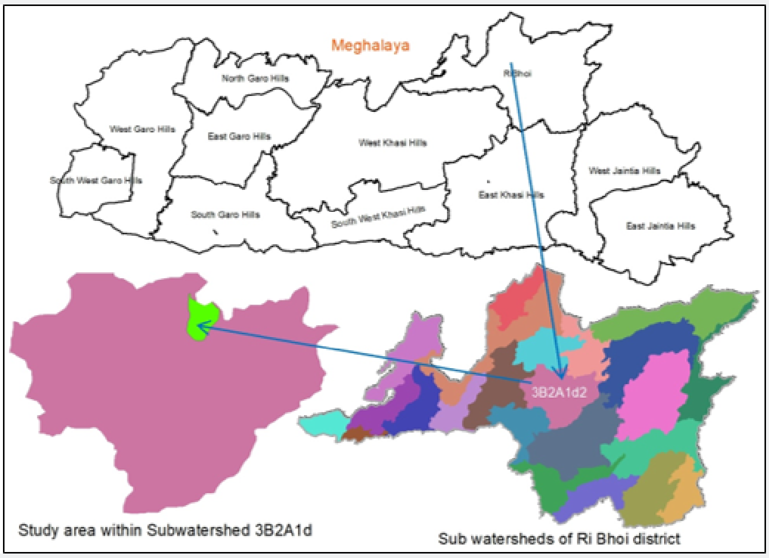

Figure 1: Location of the study area.

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Materials and Methods

Visual image interpretation technique was applied to extract various land use land cover classes existing in the study area. Google satellite image available in open source software QGIS 3.14 was used to prepare land use land cover map (LULC) of the study area.Various scene elements like tone, texture, shape, size and association were considered during image interpretation. Ground truth data were collected to confirm various land use classes [17]. The slope map was derived from 10m CartoDEM generated under SISDIP project for Meghalaya at North Eastern Space Applications Centre (NESAC). Lithology and physiography map generated by NESAC under different projects were updated with Goggle image. Grid map of 1 ha area was generated by using ArcGIS software. All these layers were overlaid in GIS environment and by using overlay function of Analysis Tools of ArcGIS 10.3 software, one composite layer was prepared. The composite layer with attributes of all input layers was used to as base map for collection of soil samples. Surface soil samples soil samples were collected from 64 locations based on variation in slope, lithology, physiography and land use land cover and recorded the location of the sample with Global Positioning System. The soil samples were tested for pH, OC, macro and micro nutrients at soil testing laboratory.

Directorate of Agriculture, Govt. of Meghalaya has entrusted NESAC to generate district wise soil fertility maps of Meghalaya. Under the project Soil health data has been collected from SHC Portal https//soilhealth.dac.gov.in. From the soil health card dashboard, grid wise soil health data has been downloaded for the Ri Bhoi district. The downloaded data is edited and brought to GIS environment compatible format. Then one point layer is generated by using soil sample location (latitude, longitude) information using ArcGIS 10.3 software. It is found that 49 samples were collected covering the study area. By combining sample points of NESAC and Soil Health Card data, one single layer was generated and used for preparation of various soil fertility maps namely pH, Organic Carbon (physical parameters); available nitrogen, phosphorus, potassium (macronutrients); Fe, Zinc, Copper and Manganese (micronutrients). The fertility maps were generated by using Spatial Analyst tools of ArcToolbox. Inverse Distance Weighted (IDW) interpolation technique was applied to generate fertility map of unknown locations based on information of known locations.

Land evaluation for soil site suitability for rice, maize and pineapple was done according to the FAO guidelines [18, 19, 20, 21]. It provides information about different opportunities and constraints for use of the land and therefore helps to take decision on optimal utilizations of resources, which is an essential prerequisite knowledge for land use planning and development. Moreover, during soil site suitability analysis main limiting factors for the agricultural production are identified. This enables decision makers viz. land use planners, land users and agricultural support services to develop a crop management plan so that such constraints can be overcome and increase the productivity. Land are categorized into different suitability classes and sub classes based on the terrain characteristics, soil properties like depth, texture, drainage, soil pH etc. and analysing existing land use [22,23].

The existing soil map prepared at 1:10,000 scale by the North Eastern Space Applications Centre in collaboration with Central Agricultural University, Borapani was used for soil site suitability evaluation for different crops. Ten thematic maps namely slope, soil depth, drainage, flooding, texture, gravel/stoniness, pH, organic matter, CEC and base saturation were generated from the soil map and one composite layer was generated by using overlay function of Analysis Tools ofArcToolbox. The composite layer with attributes of all input layers was used to compare the requirements ofrice, maize and pineapple with the existing land quality and values of degree of limitation ranging from 0 (suggesting no limitation) to 4 (suggesting very severe limitation) were assigned [24]. Suitability classes of land were assigned according to the number and the intensity of limitations and classified as Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3) and Not Suitable (N). Based on present land use land cover, soil site suitability for different crops and soil fertility status, an alternate land use action plan was prepared for the study area by using ArcGIS software.

Results and Discussions

Land use land cover

From the LULC map it was found that forest is the most dominant LULC class followed by agriculture, builtup, scrub and water body (Figure 2). The predominant trees of the forests are Quercus spp. Castanopsis spp. Toona ciliate, Albizia spp. Aporosa spp. Bahunia variegate, Duabanga spp. and Ficus spp. Forest was classified into dense and open forest that are distributed over 140.77(52.94%) and 78.82 ha (29.64%) area respectively. It was also known from interaction with villagers that because of human interventions dense forest has become open forest over the time. Agriculture is the second dominant land use within the micro watershed that cover 48.58 ha area. It is found that 39.82 (14.97%) ha area is used for cultivation of different crops like rice, tomato, beans, ginger, turmeric, pea etc. Areca nut, jackfruit, orange, guava, litchi, bay leaf and other indigenous fruits like soh broi, sohramdieng, soh thri are major agricultural plantation crops grown in the study area that cover 8.76 ha (3.29%) area. Built up area is consist of 6 villages that covers 41.97 ha area. Scrubs and water body are distributed over 33.25 ha and 1.35 ha area respectively. It was observed that water body is consisting of ponds that are used for fish raring.

Soil fertility maps

Nine fertility maps namely pH, OC (Physical parameters); N, P, K (Macro-nutrients) and Zn, Fe, Cu, Mn (Micro - nutrients) were generated by interpolating point layer generated from location of soil sampling sites (Figure 2). From the study it is found that

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moderately acidic soils are the most dominant soils that covers 195.92 ha (73.68%) area which is followed by slightly acidic soil that cover 67.48 ha area. Very negligible areas are covered by strongly acidic and neutral soils. Soils of the micro watershed are very rich in organic carbon. Available nitrogen is high and medium in 215.04 ha and 50.88 ha area respectively. Availability of phosphorus in soils of the study area is medium in 64.82 % area followed by high and low in 34.85% and 0.34% area respectively. It is found that the availability of potassium is medium in 209.53 ha area followed by low and high in 46.66 and 9.73 ha area respectively. Soils of the entire micro watershed are sufficient in iron and copper.Zinc and manganese is deficient in 58.18 ha (21.88%) and 10.42 ha (3.92%) area. Very negligible area (1.87ha) is found to be deficient in iron (Table 1).

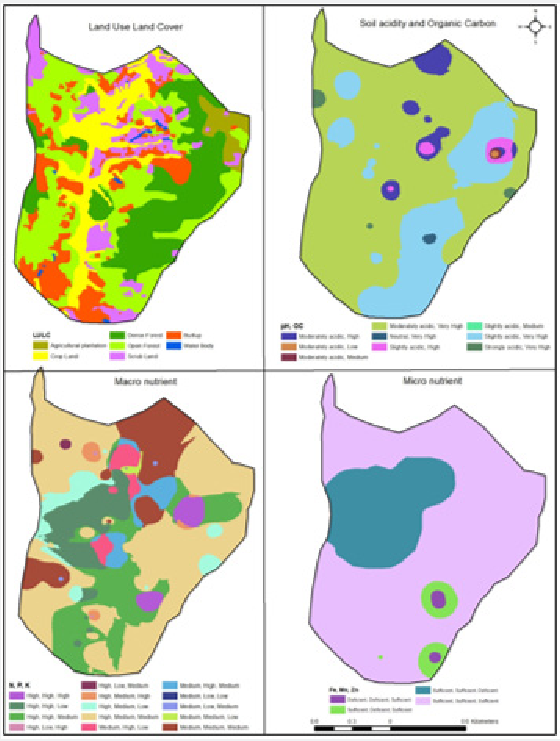

Figure 2: Land use land cover and soil fertility map.

Table 1: Area under different fertility classes.

Parameters	Class	Area (ha)	%area
pH	Slightly acidic	67.48	25.38
	Moderately acidic	195.92	73.68
	Strongly acidic	1.85	0.7
	Neutral	0.67	0.25
OC	Very High	250.56	94.22
	High	14.77	5.55
	Medium	0.37	0.14
	Low	0.22	0.08
N	High	215.04	80.87
	Medium	50.88	19.13
P	High	92.66	34.85
	Medium	172.36	64.82
	Low	0.89	0.34
K	High	9.73	3.66
	Medium	209.53	78.79
	Low	46.66	17.55

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Fe	Deficient	1.87	0.7
	Sufficient	264.05	99.3
Mn	Deficient	10.42	3.92
	Sufficient	255.5	96.08
Zn	Deficient	58.18	21.88
	Sufficient	207.74	78.12
Cu	Sufficient	265.92	100

Evaluation of soil site suitability for crops

During ground truth data collection, it was observed that rice, maize and pineapple are the major crops grown by the farmers of the study area. Therefore, suitable areas were identified for expansion of these crops. Soil site suitability analysis was carried out over 151.89 ha areas which includes open forest, scrub and crop lands. Dense forest and agricultural plantations were not considered for the land evaluation. From the study it is found that 95.40ha (62.81%) is not suitable for rice cultivation which is mostly open forest and scrub land. Since the study area is a hilly area, only intermontane valleys are suitable for rice cultivation. It is found that the highest area of 33.91 ha is moderately suitable for rice because the soils are moderately well drained, sandy clay loam in texture and moderately acidic in nature. Rice is marginally suitable in 19.80 ha area because of the soils are well drained to somewhat excessively drained. Highly suitable areas are found in 2.78 ha area which is imperfectly drained and soil texture is clay loam. It is found that maize and pineapple area suitable in about 90% area because soils are well drained and soil texture is loam.Maize is highly suitable in 19.75 ha area and moderately and marginally suitable areas cover 73.94 ha and 50.70 ha area respectively. Pineapple is moderately suitable in 64 ha area followed by 76.40 ha marginally suitable areas. Only 3.86 ha is found highly suitable for pineapple (Table 2 and Figure 3).

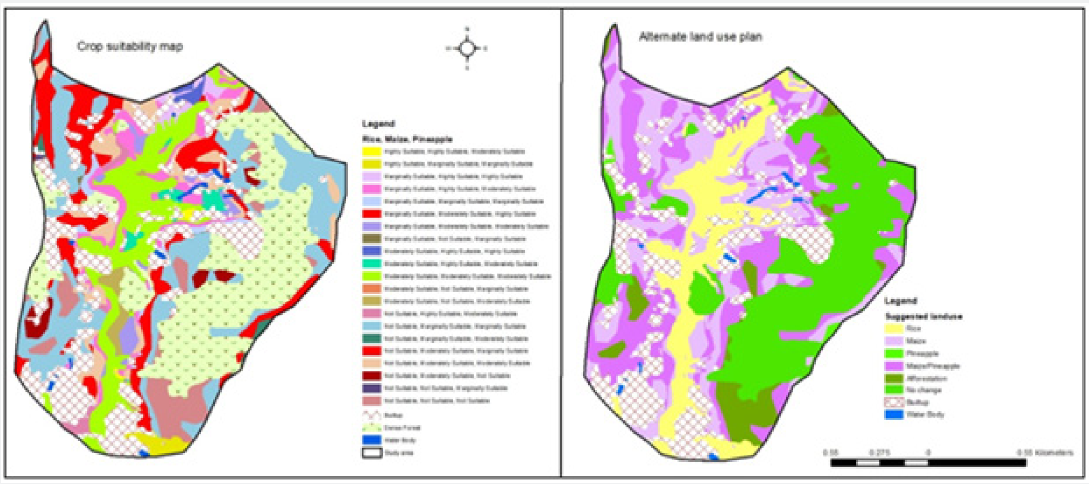

Figure 3: Crop suitability and suggested land use map.

Table 2: Area under different suitability classes.

Suitability class	Rice	Maize		Pineapple		
	Area (ha)	%area	Area (ha)	%area	Area (ha)	%area
Highly Suitable	2.78	1.83	19.75	13	3.86	2.54
Moderately Suitable	33.91	22.33	73.94	48.68	64	42.13
Marginally Suitable	19.8	13.04	50.7	33.38	76.4	50.3
Not Suitable	95.4	62.81	16.26	10.71	16.38	10.79

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Alternate land use plan

The alternate land use was suggested based on present land use and crop suitability (Figure 3).During field visit it was noticed that crop lands are associated with lands which are lying unitized. From crop suitability analysis it is found that scrub lands nearby by crop growing areas are suitable for rice. Therefore, suitable scrub lands are suggested for growing of rice along with existing crop land with imperfect soil drainage (4.33ha). Crop lands which are not suitable for rice and situated on gently slopes with moderately well drained soils are suggested for maize cultivation (48.73ha). Pineapple is suggested in 1.3 ha crop land which are not suitable for rice and maize. Traditionally farmers of Meghalaya cultivate different crops by preparing buns between trees. Therefore, based on crop suitability, maize and pineapple are suggested in scrub and open forest so that without disturbing the existing vegetation open spaces can be utilized for crop production (54.33 ha). Open forest and scrubs covering which are not suitable for any crops are suggested for afforestation (13 ha). Dense forest and agricultural plantations are not considered for any alternate use.

Conclusions

The study revealed that soils of the watershed are slightly acidic to moderately acidic in reaction with high soil organic carbon content. Soils are rich in available nitrogen and medium in phosphorus and potassium. Soils of the entire micro watershed are sufficient in iron and copper. Zinc and manganese is deficient in some areas. Based on soil properties and site characteristics, suitability for different crops and interventions has been suggested. Low lying crop and scrub lands are suggested for rice. Maize is suggested in upland crop lands where rice is not suitable. Mize and pineapple is suggested in suitable areas covering open forest and scurb lands. Afforestation is suggested where the land is not suitable for any cultivation. Sustainable resource utilization is expected with the suggested land use which may give optimum benefit from the crops. Minimum damage to the soil will be induced if the soil fertility maps are used for proper soil management and limitations are followed for any future agricultural use.

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