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GIS APPROACH FOR EXPLORING POTENTIAL LAND FOR ORANGE CULTIVATION IN HARIPUR UPAZILA UNDER THAKURGAON DISTRICT OF BANGLADESH

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Abstract: A Geographic Information System (GIS) approach has been made to search areas in Haripur upazila (sub-district) under Thakurgaon district of Bangladesh that meet the agro-ecological requirements for orange cultivation. The use of GIS tools seems to be appropriate as the agro-ecological conditions are spatial in nature. A GIS based overlay analysis has been used to identify the potential areas for orange production that meet both agro-climatic and land/soil requirements where shrubs/bushes or upland cropping are the present dominant land use pattern. The analysis shows that Haripur upazila consists of diverse categories of orange suitable areas. The most suitable region for orange cultivation has been found to be the north-eastern and southern part of the upazila, consisting of the soil group – 'Pirgachha' with an area coverage of about sq. km 20.54 (2,054 ha). The moderately suitable region has been marked in the northern part of the upazila covering an area of 73.83 sq. km (7383 ha) and the soils belong to the groups – 'Ranisankail', 'Jamun', 'Pamol', 'Jagdal', 'Baliadangi' and 'Domar'. An area of about 86.3 sq. km (8630 ha) in the south central part of the upazila appeared to be non-suitable for orange cultivation. A model approach has thus been developed in this study for identifying potential areas that can be used to select demonstration sites for orange cultivation.

Key words: GIS approach, orange, potential area.

INTRODUCTION

The potentiality of the horticulture sector has never been fully exploited in Bangladesh. Of the total 140,900 sq. km (14.09 million ha) of arable land in the country, area under cultivation for horticultural crops is about 6,900 sq. km (0.69 million ha) that contribute to only 5 percent of the total cropped area (BBS 1996). The present production of horticultural crops is far below the requirement and the

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demand of the crops will increase further by 2010. By 2010, the fruit demand will be around 3.73 million tons from the current requirement of 3.04 million tons (Hossain 1998).

More than 90 percent of the world orange production is confined to latitudes 20 degrees and 40 degrees in both northern and southern hemispheres and only 10 percent between the latitudes 20 degrees north and south of the equator (Wijeratne 2004). Thus, Bangladesh has very good and bright prospect for large scale cultivations of this citrus fruit. Unfortunately, the fruit production has been at a low phase as the early agricultural policies of the country reflected more concern for self-attainment in cereal production and other field crops without much attention for the development of fruit sector. With other fruits, orange cultivation in Bangladesh has remained unexploited. At present, orange is cultivated only in very limited areas in Sylhet and remote areas of Chittagong Hill Tracts, Rangpur and Panchagarh districts. Orange cultivated area in Bangladesh is only about 3.00 sq. km (300 ha). The estimated annual average yield of orange in Bangladesh is about 1150 kg ha^{-1} (BBS 2000), which is negligible compared to other major citrus growing countries, where the annual average orange yield is about 40 m t ha^{-1} (Wijeratne 2004). In the highland areas, the environmental conditions approximate the temperate climate and are not suitable for rice or other field crops. This provides an opportunity for orange cultivation. In Bangladesh, orange growing area has increased very slowly over the years. During 1995 to 2000, the area under orange cultivation increased to only 3.44 sq. km (344 ha) which is only 0.28 sq. km (28 ha) more than what was in 1985 (BBS 2000).

Until now, the potential land for orange in the north-western part (Rajshahi division) has remained unexplored. Only few scattered trees are found in some home gardens. The success story of growing orange in Darjeeling and Shiliguri areas in India has made the argument that why it cannot be successful in the neighbouring areas i.e., north-western part of Bangladesh, having more or less similar high land topography with optimal rainfall, temperature regime and suitable soils. The poverty of a large number of people could be alleviated through cultivation of orange in vast highlands under GO/NGO patronization. The farmers need proper guidance to select appropriate land, soils and varieties for orange cultivations. Recently some private entrepreneurs have started to grow orange in the northern and north-western part of the country inspired by the cultivation of orange in neighboring parts of India, without any proper guidance. Factors involved in limiting the cultivation of orange include lack of capital and bank loan, absence of scientific method of cultivation, absence of proper nursing of orange gardens and lack of adequate transport and market facilities.

It has been recognized that land suitability is assessed as part of a 'rational' cropping system (FAO 1976) and optimizing the use of a piece of land for a specified use (Sys et al 1991) should be based upon its attributes (Rossiter 1996). Assessment of land and soil suitability for crops is concerned solely with the physical suitability of the environment for producing crops of interest (Brammer 1997). Although criteria may vary, they are essentially based on climate, soil, topography or relief and water availability which are the most important categories of environmental information required for judging land suitability for specific crop (Ghaffari et al 2000) and wise planning of land use particularly to maximize crop production (Hoque et al 2004).

The GIS approach provides a sophisticated way of handling relationships between site-specific factors affecting crop production. GIS techniques have been used for farm-based assessments at national and regional scales for many years (Usery et al 1995) since agriculture is intrinsically a geographical practice (Hoque et al 2004). Keeping this in mind, a spatial analysis has been made by using GIS tools. The objective of the work is to locate potential land and soil for orange cultivation in Haripur upazila under Thakurgaon district to provide a tool for selecting demonstration site/location for orange cultivation. This would assist policy makers and motivate the farmers for growing orange in appropriate land and soil. The location specific technologies have to be generated through large number of on-farm trials and frontline demonstrations. Therefore, exploring and mapping potential areas for orange cultivation is regarded as mandatory for location specific successful demonstration.

MATERIALS AND METHODS

Study Area

Haripur upazila (sub-district) consisting of six unions is situated in the north-western part of Bangladesh and the south-western part of Thakurgaon district. It is located between $25^{0}45'$ to $26^{0}01'$N and $88^{0}04'$ to $88^{0}14'$E. The Upazila covers an area of 201.15 sq. km., which entirely falls under Hiamlayan Piedmont Alluvial Plain, - the physiographic unit having nearly level to slightly undulating highland (94.87 sq. km), medium highland (74.30 sq. km) and medium lowland (11.94 sq. km) (SRDI 1998)

Climatic Data

Agro-climatic information (Fig. 1) was obtained from secondary source (FAO/UNDP 1988). The suitability of that area from climatic point of view was also evaluated by comparing the climatic requirement for orange with the climatic conditions of the area. An analysis of the climatological data (FAO/UNDP 1988) of Haripur area indicates that the mean daily temperature of this area (T5e3

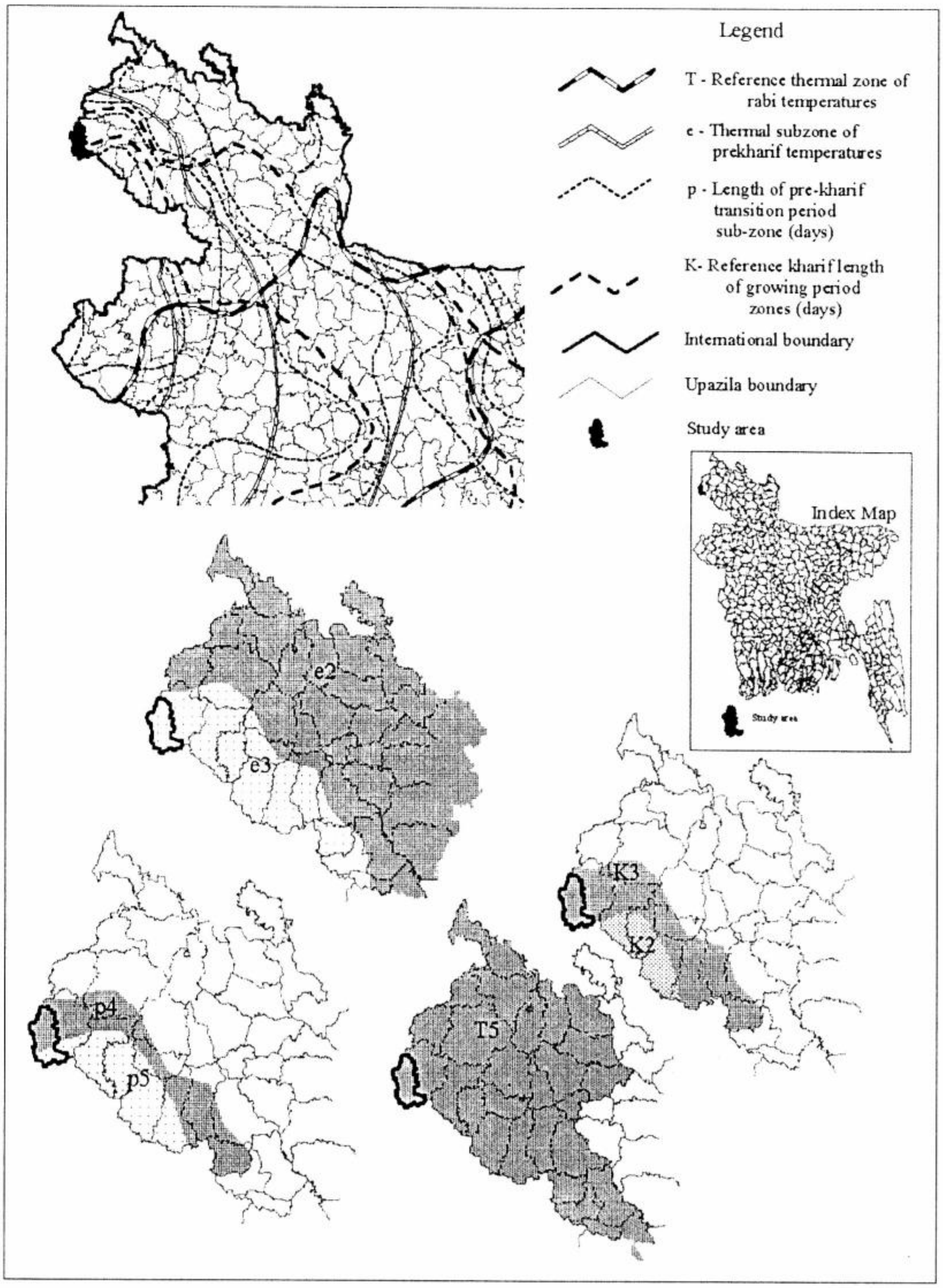

Fig.1 Reference Moisture and Thermal Zones (FAO/UNDP,1988)

thermal zone) satisfies the regional optimum requirement. Further analysis of temperature data reveals that the frequency of occurrence of temperature below 10^0C is only 25-35 days. At this temperature, the offshoot sprouting will remain dormant. However, this will not create a serious problem as no such problem is noticed in the existing plantations. Again, the frequency of occurrence of temperature >40^0C is only 5-10 days. An analysis of long-term rainfall data and stored soil moisture to one-meter depth indicates that there is a period of moisture shortage or dry period of maximum 50-60 days in this region (K3p4 and K3p5 moisture zone). On the other hand, there is a humid or wet period when the total rainfall is continuously greater (700-1200 mm) than the potential evapotranspiration (PET) of crops. During this period, excess water from the soil profile needs to be drained out timely. In the rabi (dry) season, the rainfall, together with the stored soil moisture in the soil profiles are nearly satisfactory to support plant growth (Rahman et al 1999).

Land and Soil Data

Data focusing land type and its quality (Table 1) along with characteristics of soils (Table 2) present in different landform were compiled as identified and mapped (Fig. 2) by SRDI in 1996 through semi-detailed soil survey. The 'Soil and Landform Map' thus prepared having 10 mapping units, which differ from each other in their bio-physical properties belonged to diverse categories of land type and soil group. This map was used as the base material for GIS based spatial analysis to locate suitable area for orange cultivation.

Factors Considered

Orange is a fruit of temperate region. The optimum mean daily temperature of the growth of orange is 23^0C to 30^0C. The growing is markedly reduced above 38^0C and below 13^0C. Active root growth occurs when soil temperatures are higher than 12^0C. Strong wind is harmful to citrus trees because flowers and young fruits fall off easily. High humidity increases the incidence of pests and diseases (Narayana et al 1994).

A well aerated soil and a sufficiently deep soil profile that can allow tap roots to penetrate to the desired depths (1-2 m) are required for growing orange trees. Light to medium textured soils having pervious layers free from stagnant water and that remain nonstick are preferred. Areas with high water table should be avoided. The pH between 5 and 8 is preferred. These requirements are to be considered while assessing land for the suitability of orange cultivation (Rahman et al 1999). As such, the factors analyzed in this study are land type, soil depth, relief, surface water recession, soil reaction, drainage, soil consistency, soil texture, soil salinity and agro-climatic zones.

Table 1 Mapping Unit (Figure 2) Based Land Quality Data and Corresponding Soil Group Identified in Haripur Upazila (SRDI 1998)

Mapping Unit	Land Quality				Identified Soil Group	
	Land Type	**Relief**	**Surface Water Recession**	**Drain-age**	**Soil Group Name**	**Approx. Area (sq. km)**
1	HL (1)	Nearly level (1)	Very early (1)	MWD (1)	Ranisankail	13.87
			Very early (1)	MWD (1)	Pirgachha	1.98
			Very early (1)	ID (2)	Jamun	7.92
			Very early (1)	ID (2)	Pamol	9.90
	MHL(3)	Nearly level (1)	Early (3)	PD (3)	Jagdal	3.96
2	HL (1)	Undulating (1)	Very early (1)	MWD (1)	Ranisankail	2.33
			Very early (1)	MWD (1)	Pirgachha	7.58
			Very early (1)	ID (2)	Pamol	1.17
3	HL (1)	Nearly level (1)	Very early (1)	MWD (1)	Pirgachha	10.98
			Very early (1)	ID (2)	Jamun	8.23
			Very early (1)	ID (2)	Jagdal	2.74
	MHL(3)	Nearly level (1)	Early (3)	PD (3)	Jagdal	4.12
4	HL (1)	Nearly level (1)	Very early (1)	ID (2)	Pamol	4.19
			Very early (1)	ID (2)	Baliadangi	1.05
			Very early (1)	ID (2)	Jagdal	3.15
	MHL(3)	Nearly level (1)	Early (3)	PD (3)	Jagdal	1.57
5	HL (1)	Nearly level (1)	Very early (1)	ID (2)	Jamun	10.33
			Very early (1)	ID (2)	Pamol	5.16
	MHL(3)	Nearly level (1)	Early (3)	PD (3)	Aamgaon	25.82
			Early (3)	PD (3)	Farabari	10.33
6	HL (1)	Nearly level (1)	Very early (1)	ID (2)	Jamun	2.61
	MHL(3)	Nearly level (1)	Early (3)	PD (3)	Aamgaon	5.23
			Early (3)	PD (3)	Farabari	5.23
7	HL (1)	Undulating (1)	Very early (1)	MWD (1)	Domar	1.18
	MHL(3)	Undulating (1)	Early (3)	PD (3)	Jamun	2.76
			Early (3)	PD (3)	Nagar Belemati	3.16
8	MHL(3)	Nearly level (1)	Early (3)	PD (3)	Gangachara	4.07
			Early (3)	PD (3)	Jagdal	3.05
	MLL (3)	Nearly level (1)	Normal (3)	PD (3)	Gangachara	2.54
9	MHL(3)	Nearly level (1)	Normal (3)	PD (3)	Farabari	2.06
	MLL(3)	Nearly level (1)	Late (3)	PD (3)	Uttargaon	1.37
10	MHL(3)	Nearly level (1)	Late (3)	PD (3)	Uttargaon	1.16
		Nearly level (1)	Late (3)	PD (3)	Lashkara	1.74
	MLL (3)	Nearly level (1)	Late (3)	PD (3)	Lashkara	4.65
		Nearly level (1)	Late (3)	PD (3)	Alshia	3.48

HL: High Land MHL: Medium High Land MLL: Medium Low Land MWD: Moderately Well Drained ID: Imperfectly Drained PD: Poorly Drained.

Figures (1, 2, 3) in the parentheses are the rating (SRDI, 1998) used in GIS approach to assess the suitability of land qualities for orange cultivation. 1 = Suitable, 2 = Moderately suitable and 3 = Non-suitable

Table 2 Data Focusing the Characteristics of Soil Identified in Haripur Upazila (SRDI 1998)

Soil Group Identified	Characteristics					
	Soil Depth* (m)	Texture	Consis-tency	Available Moisture	Salinity	Reaction (pH)
Ranisankail	1.0 - 1.15(1)	Sandy Loam (2)	Friable (1)	Low (3)	Non saline (1)	Strongly acidic (1)
Pirgacha	0.75 - 1.0(1)	Loam (1)	Friable (1)	Medium (1)	Non saline (1)	Slightly acidic (1)
Domar	0.75 - 1.0(1)	Sandy Loam (2)	Friable (1)	Low (3)	Non saline (1)	Slightly acidic (1)
Jamun	0.75 - 1.0(1)	Loam (1)	Friable (1)	Medium (1)	Non saline (1)	Slightly acidic (1)
Pamol	0.75 - 1.0(1)	Loam (1)	Friable (1)	High (1)	Non saline (1)	Slightly acidic (1)
Jagdal	0.75 - 1.0(1)	Loam (1)	Friable (1)	Medium (1)	Non saline (1)	Slightly acidic (1)
Baliadangi	0.75 - 1.0(1)	Loam (1)	Friable (1)	Medium (1)	Non saline (1)	Slightly acidic (1)
Aamgaon	0.50 - 1.0(2)	Loam (1)	Friable (1)	High (1)	Non saline (1)	Strongly acidic (1)
Uttargaon	0.50 - 1.0(2)	Clay Loam (1)	Friable (1)	Low (3)	Non saline (1)	Strongly acidic (1)
Farabari	0.50 - 1.0(2)	Loam (1)	Friable (1)	Medium (1)	Non saline (1)	Slightly acidic (1)
Gangachara	0.50 - 1.0(2)	Loam (1)	Friable (1)	High (1)	Non saline (1)	Strongly acidic (1)
Alshia	0.50 - 1.0(2)	Clay (3)	Sticky (3)	Low (3)	Non saline (1)	Slightly acidic (1)
Lashkara	0.50 - 1.0(2)	Clay (3)	Firm (2)	Low (3)	Non saline (1)	Slightly acidic (1)
Nagar Belemati	0.50 - 1.0(2)	Sand (3)	Loose (3)	Low (3)	Non saline (1)	Slightly acidic (1)

*Source: SRDI, 1965

Figures (1, 2, 3) in the parentheses are the rating (SRDI, 1998) used in GIS approach to assess the suitability of soil characteristics for orange cultivation. 1 = Suitable, 2 = Moderately suitable and 3 = Non-suitable

GIS Approach of Spatial Analysis

Once all requisite data were collected, these were entered into ARC/INFO software where soil and landform, administrative boundaries (upazila, union), road network, river/water bodies and agro-climatic maps were digitized using a graphic tablet. On completion of data input digitally, a set of covers was created with two types of data – spatial and topology attribute. They all were at a scale of 1: 50,000 (Fig. 2) with which implementation of a clean overlay procedure was followed even the data sources were diverse. The digital maps were retrieved with the transformation of the map projection into Arc View 3.2 compatible LCC (Lambert Conformal Conic) format from the geographic one followed by conversion of the covers to shape files where all the data focusing agro-climate, land and soil were incorporated to create database in the form of attribute table. Attribute data were subsequently used as the characteristics of the geographic features i.e. agro-climate, land and soil.

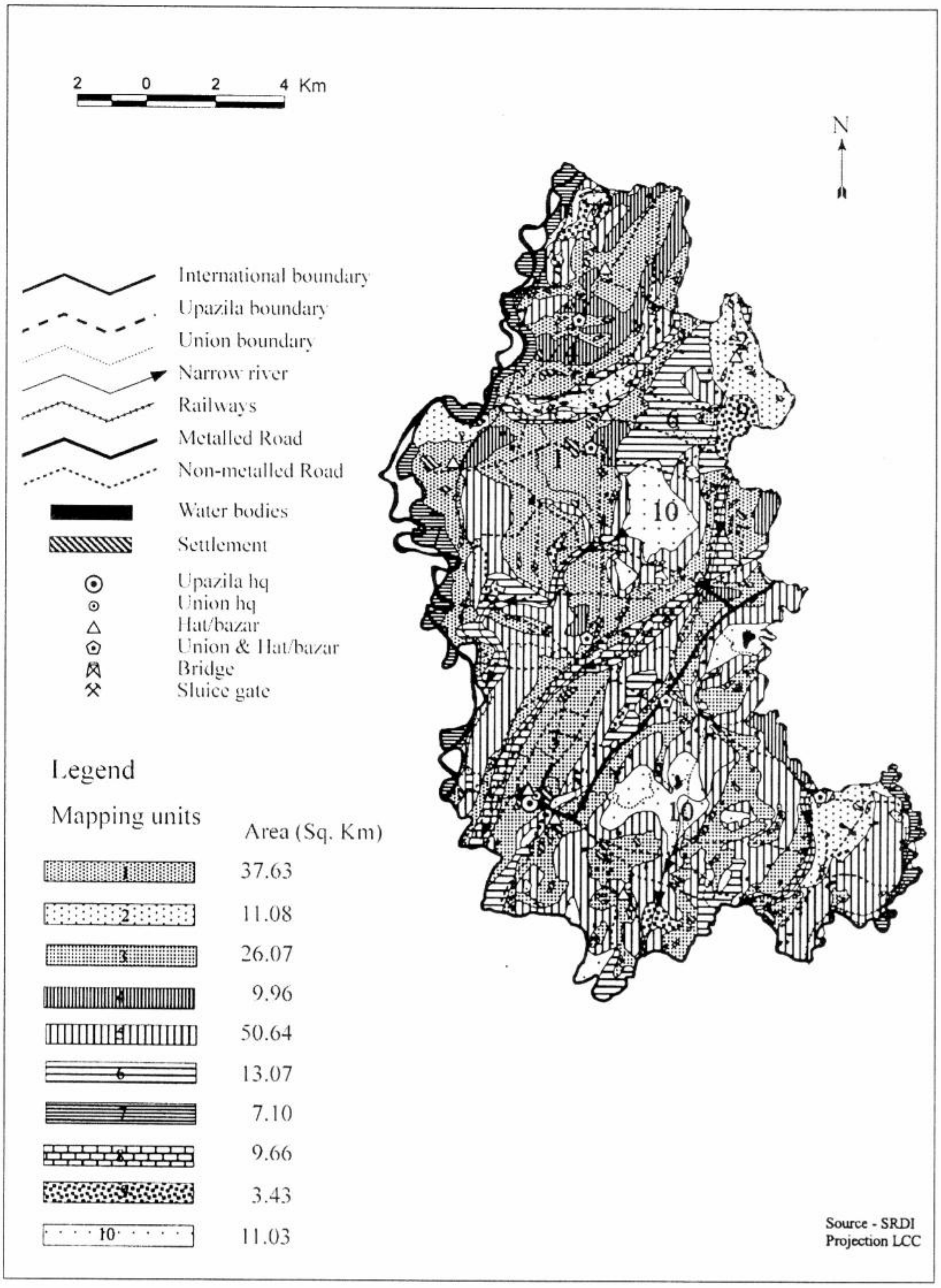

Fig. 2 Soil and Landform Map: Haripur Upazila, Thakurgaon District

After the creation of requisite database all the attribute data were displayed in a common view as layers or themes and data was handled through a vector-based approach, which generated new polygon coverage when factors were combined. The individual data layer or theme was then converted to raster form for spatial analysis. In raster data model, links are implicit in the way that specific attributes are assigned to individual layers, and the values specified for the pixels or cells in each layer. By allowing links between spatial and attribute databases, a series of operations such as select, search and overlay can be performed (Rhind 1990). In Arc View, spatial analysis tools make relationships between map layers or themes based on variables or data input for suitability analysis and combine them to create composite map. Such map could be used to locate potential or suitable area (ESRI 1996) for particular use.

Once data layers were converted from vector to raster form, then Arc View spatial analysis tools were activated through which analysis by using built-in map query option was done. The themes were thus queried by selecting out all the factors and setting up of corresponding suitability scale (Table 1 and 2) to them as formulated in *crop suitability scale or rating chart* (SRDI 1998). Based on this chart, values 1, 2 and 3 were assigned correspondingly to each theme in terms of suitability scale or class, i.e. 1 for '*Suitable*', 2 for '*Moderately suitable*' and 3 for '*Not suitable*'. Afterward, an evaluation was done to obtain the different suitability level with area and extent for mapping units assuming them as spatial phenomenon. Due to limitation of source data, suitability of soils in different land types was assessed separately assuming the occurrence of all soils as 'dominant' in a mapping unit. Once suitability for orange cultivation was assessed for all soils in different land types, a composite suitability map was produced by employing overlay procedure. The output map could be used in selecting most suitable area for orange cultivation.

RESULTS AND DISCUSSION

The spatial analysis using GIS approach based on agro-climatic information and semi-detailed soil survey data identified three categories of soils in different land types in terms of their suitability scale (i.e. suitable, moderately suitable and non-suitable) for orange cultivation. Study revealed that no mapping unit of 'Soil and Landform Map' could be identified to be as absolutely suitable for growing orange owing to diversity of land type with soil groups differing in their characteristics within individual mapping unit. In most mapping units, high lands were explored to be suitable and moderately suitable depending on their soil suitability for orange cultivation to different extent. Only 'Pirgachha' soil group was found to be suitable whereas 'Ranisankail', 'Jamun', 'Pamol', 'Jagdal', 'Baliadangi' and 'Domar' soil groups were found to be moderately suitable. On the contrary, medium high land and medium low land in different mapping units were marked to be non-suitable irrespective of soils and their characteristics. Mapping unit-wise suitability scale of land and soil as explored by GIS approach with area in sq. km (compiled from semi-detailed soil survey data) is presented in Table 3.

Table 3 Suitability Levels of Soil Mapping Units with their Area and Extent (Covered by Soil Groups in Different Land Types) as Explored by GIS Approach for Orange Cultivation in Haripur

Mapping Unit		Area and Extent of Different Suitability Levels Explored by GIS Approach			Overall Suitability level of Mapping Unit (Assigned)
No.	**Total Area (Sq. Km)**	**Suitability Level**	**Area Sq. Km)**	**Extent (%)**	
		Suitable	1.98	5.26	Predominantly
1	37.63	Moderately Suitable	31.69	84.22	Moderately Suitable
		Non-Suitable	3.96	10.52	
		Suitable	7.58	68.41	Dominantly Suitable with
2	11.08	Moderately Suitable	3.50	31.59	Some Moderately Suitable
		Non-Suitable	--	--	
		Suitable	10.98	42.12	Equally Suitable and
3	26.07	Moderately Suitable	10.97	41.08	Moderately Suitable
		Non-Suitable	4.12	15.80	
		Suitable	--	--	Predominantly
4	9.96	Moderately Suitable	8.39	84.24	Moderately Suitable
		Non-Suitable	1.57	15.76	
		Suitable	--	--	Dominantly Non-suitable
5	51.64	Moderately Suitable	15.49	30.00	with Some Moderately
		Non-Suitable	36.15	70.00	Suitable
		Suitable	--	--	Predominantly
6	13.07	Moderately Suitable	2.61	19.96	Non-suitable
		Non-Suitable	10.46	80.04	
		Suitable	--	--	Predominantly
7	7.10	Moderately Suitable	1.18	16.62	Non-suitable
		Non-Suitable	5.92	83.38	
		Suitable	--	--	Non-suitable
8	9.66	Moderately Suitable	--	--	
		Non-Suitable	9.66	100.00	
		Suitable	--	--	Non-suitable
9	3.43	Moderately Suitable	--	--	
		Non-Suitable	3.43	100.00	
		Suitable	--	--	Non-suitable
10	11.03	Moderately Suitable	--	--	
		Non-Suitable	11.03	100.00	

Rahman et al (1999) described the prospect of growing orange in such land and soils of Thakurgaon and Panchagarh districts. But the area occupied by different land types and soil groups varying in suitability scale within a mapping unit could not be delineated as the 'Soil & Landform Map' used as base map in this assessment was produced through semi-detailed soil survey with which generally soil association based mapping is conducted. This would lead to inconvenience in finding out the most potential cultivable area. To locate potential orange cultivable area more conveniently, mapping units were further classified based on the extent of area coverage differing in the scale of land and soil suitability as explored by the GIS approach (Table 3 and Fig. 3), e.g., *'Predominantly suitable'* (mapping unit has >80% suitable area), *'Dominantly suitable with some moderately suitable'* (mapping unit has 60% - 80% suitable plus 20% - 40% moderately suitable area) etc (Table 3).

For orange, the most suitable region has been identified in the north-eastern and in the southern part of the upazila, where moderately well drained 'Pirgachha' soil covers most of the area. The moderately suitable region covers up most of the northern portion of the upazila, which has an area of moderately well drained high land having sandy loam soil groups – 'Ranisankail' and 'Domar'. Imperfectly drained high land consisting of loamy soils like 'Jamun', 'Pamol', 'Jagdal' and 'Baliadangi' are also moderately suitable for growing orange. The non-suitable region for orange cultivation is perhaps the large region covering most of the south central portion of the upazila. This area is occupied by medium high land consisting mainly of loamy soils, e.g., 'Jagdal', 'Gangachara', 'Aamgaon', 'Farabari' etc. and medium low land belonging primarily to clay textured soils like 'Lashkara' and 'Alshia' that are almost exclusively suited for field crop cultivation (Fig. 2 and Tables 1; 2).

It is evident from the study that same soils (e.g., 'Jamun' and 'Jagdal') do not show same scale of suitability due to their existence in different land types (Table 1). Therefore, land quality might be the dominating parameter in detecting the scale of soil suitability for orange cultivation. Suitable land is assumed to be cultivated with no or very low inputs and expected to have > 80 percent attainable yield of crop. Moderately suitable land is expected to have a crop yield of 60-80 percent under optimal conditions with practicable and economic inputs. Non-suitable land is assumed to have severe limitations which could rarely or never be overcome by economic use of inputs or management practices (FAO 1976; Dent and Young 1981). Hence, in case of orange cultivation in Haripur upazila, it may be assumed that suitable areas have a high potential of orange yield from year to year. Moderate suitable areas have limitation in orange production potentials only for its sandy loam texture and imperfect drainage conditions. This is evident from the output map that there is a considerable scope of bringing more suitable areas

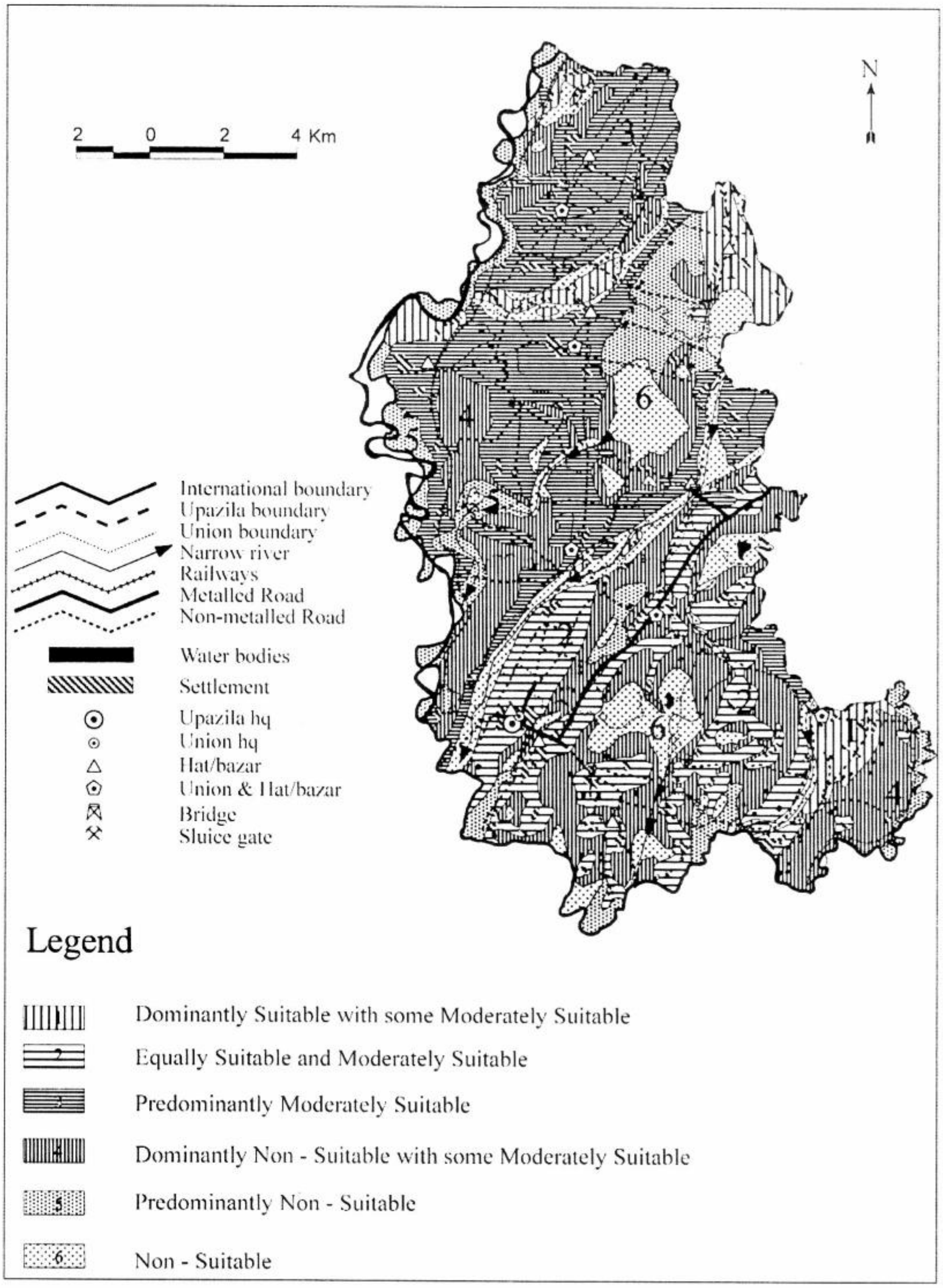

Fig. 3 Orange Suitable Area: Haripur Upazila, Thakurgaon District

under orange cultivation from moderate suitable class with minor improvements in the internal drainage system. On the other hand, in non-suitable areas, the limiting factors are seasonal inundation, late surface water recession, extreme soil acidity, heavy soil consistency and poor drainage, which could be overcome by expensive land development practices. The area for each of the suitable class was calculated. Finally, the queries were combined to create a composite orange suitability map. Such map could be used to locate potential or suitable area for orange cultivation. Moreover, orange requires careful attention. Therefore, it is extremely important to train-up the growers on all aspects of production technologies from the site selection up to harvesting and processing.

In this study, all the factors that affect orange production could not be considered but the major land and soil factors together with agro-climate were taken into account for assessing and mapping orange suitable area. Although the prototype suitability maps appear to provide useful information on the most favourable parts of Haripur upazila, there are, however, unquestionably other factors that could be considered. For orange, the factors that need to be incorporated into the GIS systems for better evaluation of suitability classes are: accessibility to transport and communication system; marketing facilities; bank loan facilities; appropriate training facilities and government price support, etc.

CONCLUSION AND RECOMMENDATION

Map (Fig. 3) and information (Table 4) generated by using semi-detailed soil survey data and GIS approach could be used as a tool for selecting proper site/area for growing orange in Haripur upazila. This way of exploring potential areas for growing orange in different region of Bangladesh may help in providing tool for the development of this sector. If necessary steps (including bank loan, training for the growers, input supply, transport and market facilities etc.) are taken by the government to develop this sector for poverty alleviation, then it might be appropriate to bring the suitable and moderately suitable areas under orange cultivation. Extension of orange cultivation needs motivation of farmers through successful demonstration. Demonstration site should be selected in suitable lands. Successful demonstration is obviously dependent on crop specific agro-environmental condition, requisite agronomic practices and balanced fertilization.

In this study, the suitability maps generated was used to choose appropriate site for future field research with orange, and to help in setting up of orange garden considering the best orange growing areas. However, suitability scale/ratings generated for different parts by GIS approach need some form of validation that goes beyond a logical construction procedure. The best validation would involve multiple sites for long term trials, plus actual observance of where the crops are grown successfully by the producers. The purpose of GIS approach in this case is to avoid such long, costly field work. Finally, GIS analysis, like simulation modeling, can identify components of a system needing research.

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