Oriental Geographer
Vol. 48, No. 2
July 2004

EXPLORING POTENTIAL SOIL AND LAND FOR WHEAT CULTIVATION: A GIS APPROACH FOR BIRAL AREA

A. F. M. M. Hoque
D. Hasan
S. M. Imamul Huq

Abstract: Wise planning of land use particularly to maximize crop production along with maintenance of soil health is attributed to suitability of concerned area or location for the cultivation of selected crops. If agro-climate permits, exploring potential land and soil is mandatory for the extension of specific cropping practice through demonstration. Since agriculture is intrinsically a geographical practice, therefore, utilities of Geographic Information System (GIS) and soil survey information could significantly be used in this regard provided relevant spatial data are supplied. A GIS based analysis has been done by considering agro-climatic and edaphic factors to locate wheat cultivable potential areas for the extension of wheat under irrigated condition at Biral upazila where rice mono-cropping is dominant land use pattern. Area calculated from output map using GIS reveals that about 81.75 sq. km (8,175 ha) of land consisting of dominant soil group 'Amnura' is suitable, while 232.43 sq. km (23,243 ha) area occupied predominantly by soil groups – 'Pirgacha' and 'Gangachara' is moderately suitable for wheat. The figures largely exceed the existing BBS data. Only 9.81 sq. km (981) ha of land covered mainly by 'Ranisankail' soil group is not suitable for wheat cultivation. This information and map presenting the potential land and soil can be used in selecting demonstration site to determine best wheat suited area at Biral.

Key words: Land quality, soil characteristics, wheat suitability and Geographic Information System (GIS).

INTRODUCTION

Bangladesh receives a large quantity of wheat (1.0-1.5 million t yr^{-1}) as food aid from wheat-surplus donor countries like USA, Australia and Canada. This has provided disincentives to the growth of wheat production (IRRI, 2000). Although wheat growing area in Bangladesh has increased steadily over the years, it further needs to be increased in order to make greater contribution towards our cereal basket. In most areas, rice mono cropping throughout the year is the common land

A. F. M. M. Hoque and D. Hasan are Scientific Officers, Soil Resource Development Institute, S. M. Immamul Huq is Professor, Department of Soil, Water and Environment, University of Dhaka. Dhaka-1000

use pattern. Consequently, degradation of soil health is occurring day by day and causing an alarming situation in terms of food security of the country. Therefore, maintenance of soil health is necessary for ensuring sustainable crop production and food security.

Although considerable factors are involved in maintaining soil health, still, wheat-rice rotation may contribute significantly in balancing plant nutrient in soil for certain period. Therefore, it is suggested to include wheat in areas under rice mono cropping system. Motivation of farmers through demonstration is essential to cultivate wheat in the suitable areas. Therefore, exploring and mapping potential areas for wheat cultivation is regarded mandatory for location-specific successful demonstration.

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). 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 *etal.*, 1991) should be based upon its attributes (Rossiter, 1996). Furthermore, land may be considered either in its present condition, or after specified improvements. 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 *etal.*, 2000).

Geographic Information System (GIS) is a computer-based information system for the capture, storage, retrieval, analysis and display of geographic features tied to a common geographic coordinate system (Goodchild, 1992; Clarke, 1997). GIS techniques have been used for farm-based assessments at national and regional scales for many years (Usery *etal*, 1995) since agriculture is intrinsically a geographical practice. A GIS based spatial analysis has been done to locate wheat cultivable potential land and soil at Biral upazila (sub-district) under Dinajpur district with a view to: provide a tool for selecting demonstration site/location for wheat cultivation in order to motivate farmers for growing wheat in their appropriate land and soil.

MATERIALS AND METHODS

The study was carried out for Biral upazila (sub-district). Data and information used in this study were obtained from secondary sources. GIS based analysis were done by using agro-climatic, land quality and soil characteristics data.

Study area

Biral upazila consisting of ten unions is situated in the north-western part of Bangladesh and the south-western part of Dinajpur district. It is located between

$25^0 30'$ to $25^0 46'$N and $88^0 27$ to $88^0 39'$E. The Upazila covers an area of 352.32 sq. km (35232 ha), of which, Barind Tract and Hiamlayan Piedmont Alluvial Plain, - the two physiographic units having nearly level to slightly undulating highland and medium highland (SRDI, 1985).

Agro-climatic data

The study area is situated in the two agro-climatic zones designated as K2p5 and K3p5 under common thermal zone T5e3 (Figure 1). Within the K2p5 zone, rabi (winter) growing period (15 October -12 February) covers 115 – 125 days with a standard deviation of 20-25 days and in K3p5 zone, rabi growing period (15 October – 17 February) covers 115 – 135 days with a standard deviation of 20 – 30 days. During rabi growing period, temperature less than 15^0C remains for 90 – 110 days and temperature less than 10^0C remains for 25 – 35 days in T5e3 thermal zone (FAO/UNDP, 1988). This low temperature is highly suitable for wheat (SRDI, 1998; Brammer,1997).

Land and soil data

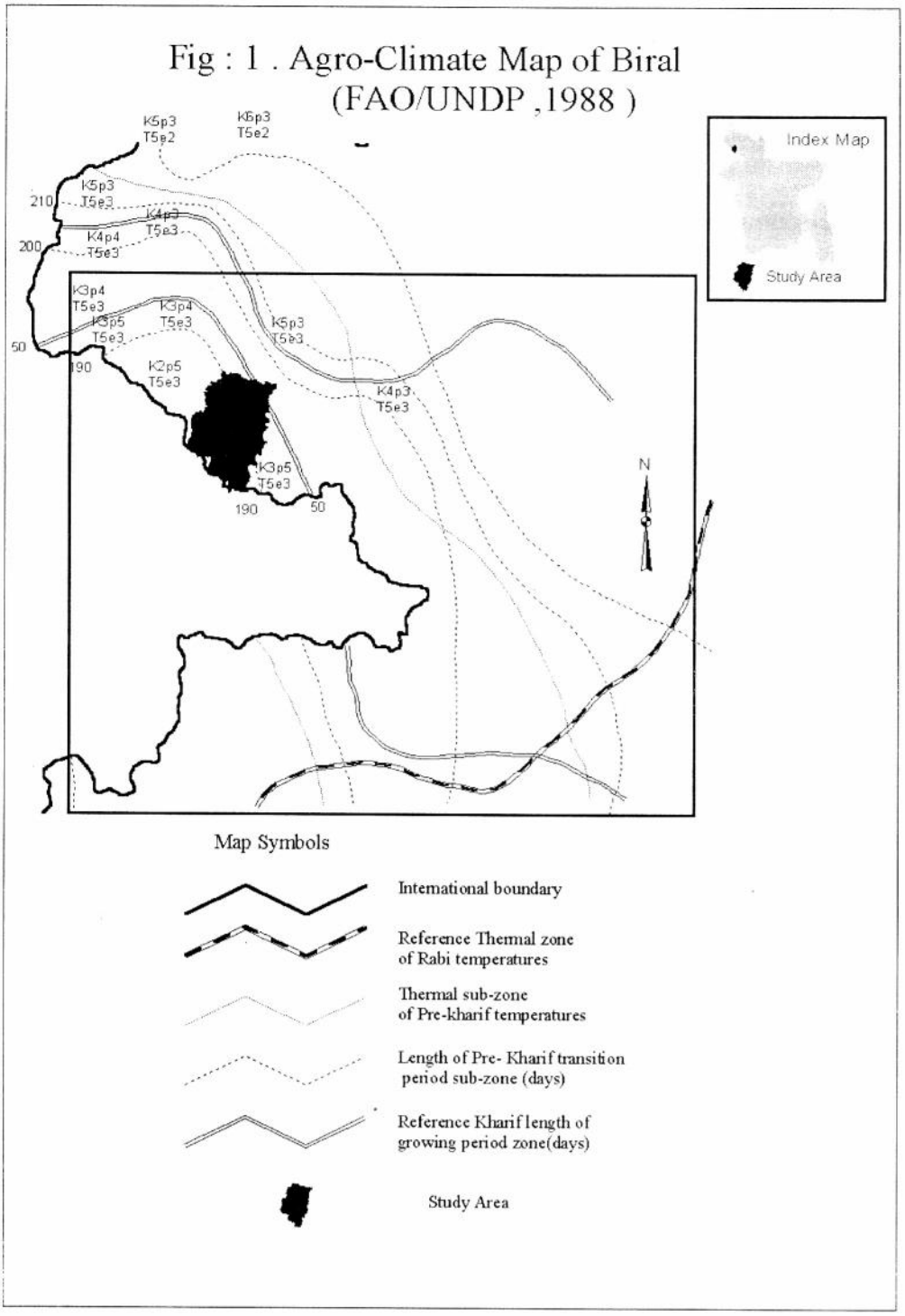
The base material used was 'Soil and Landform Map' (Figure 2) for GIS analysis. Data concerning land quality and soil characteristics were compiled (Table 1) from this map derived from a systematic approach of semi-detailed soil survey as conducted by SRDI in 1985. Data were compiled on the basis of 'dominant' or 'lead' land type and soil group(i.e. alike soil series in characteristics) in individual mapping unit of the 'Soil and Landform' map.

Table 1: Mapping Unit (Figure 2) Based Land Quality and Soil Characteristic Data (SRDI, 1985) Used in GIS Analysis to Locate Wheat Cultivable Potential Land and Soil for Biral area.

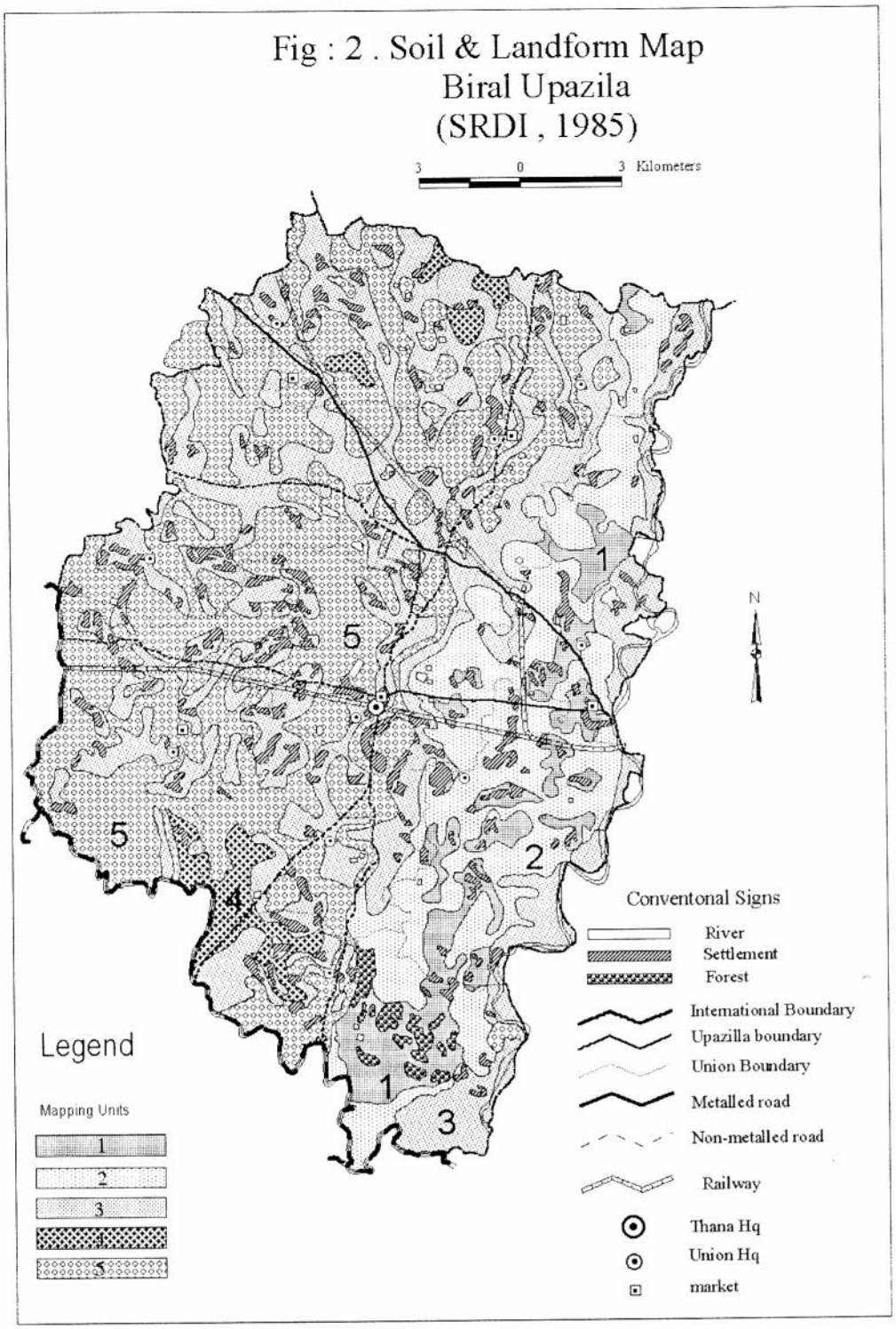
Mapping Unit	Land Quality			Soil Characteristics					
	Land type	Relief	Drai-nage	Water Recession in Winter	Dominant Soil group	Texture	Consis-tency	Salinity Status	Reaction (pH)
1	HL	Level	ID	Very early	Amnura	Loam	Friable	NS	Slightly acidic
2	MHL	Level	PD	Early	Amnura	Loam	Friable	NS	Slightly acidic
3	HL	Level	ID	Very early	Pirgacha	Loam	Friable	NS	Strongly acidic
4	HL	Undu-lating	ID	Very early	Ranisanksai l	Sandy loam	Friable	NS	Strongly acidic
5	MHL	Level	PD	Early	Ganga-chara	Loam	Friable	NS	Strongly acidic

Note: HL = High Land, MHL = Medium High Land, ID = Imperfectly Drained, PD = Poorly Drained and NS = Non Saline.

Fig : 1 . Agro-Climate Map of Biral
(FAO/UNDP ,1988)



EXPLORING POTENTIAL SOIL AND LAND



GIS analysis

GIS techniques were applied starting with digitization of complete coverage of 'Soil and Landform Map' of the study area at a scale of 1:50000 by using ARC/INFO software. Upon completion of data input digitally, a map database was created with two types of data i.e. spatial and topology attribute. The digital map was retrieved with the transformation of the map projection into LCC (Lambert Conformal Conic) from geographic under ArcView environment followed by the conversion of the cover to shape file to create database in the form of attribute table.

Once the database was created by the incorporation of agro-climate, land and soil data in terms of 'dominant' soil group of a mapping unit as spatial attribute, then all the attribute data were displayed in a common view as layer or themes or objectives. On conversion of all the displayed attribute data from vector to raster form, spatial analysis using weighted overlay method was employed for suitability assessment. In ArcView, model builder extension is used as spatial analysis tools that 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).

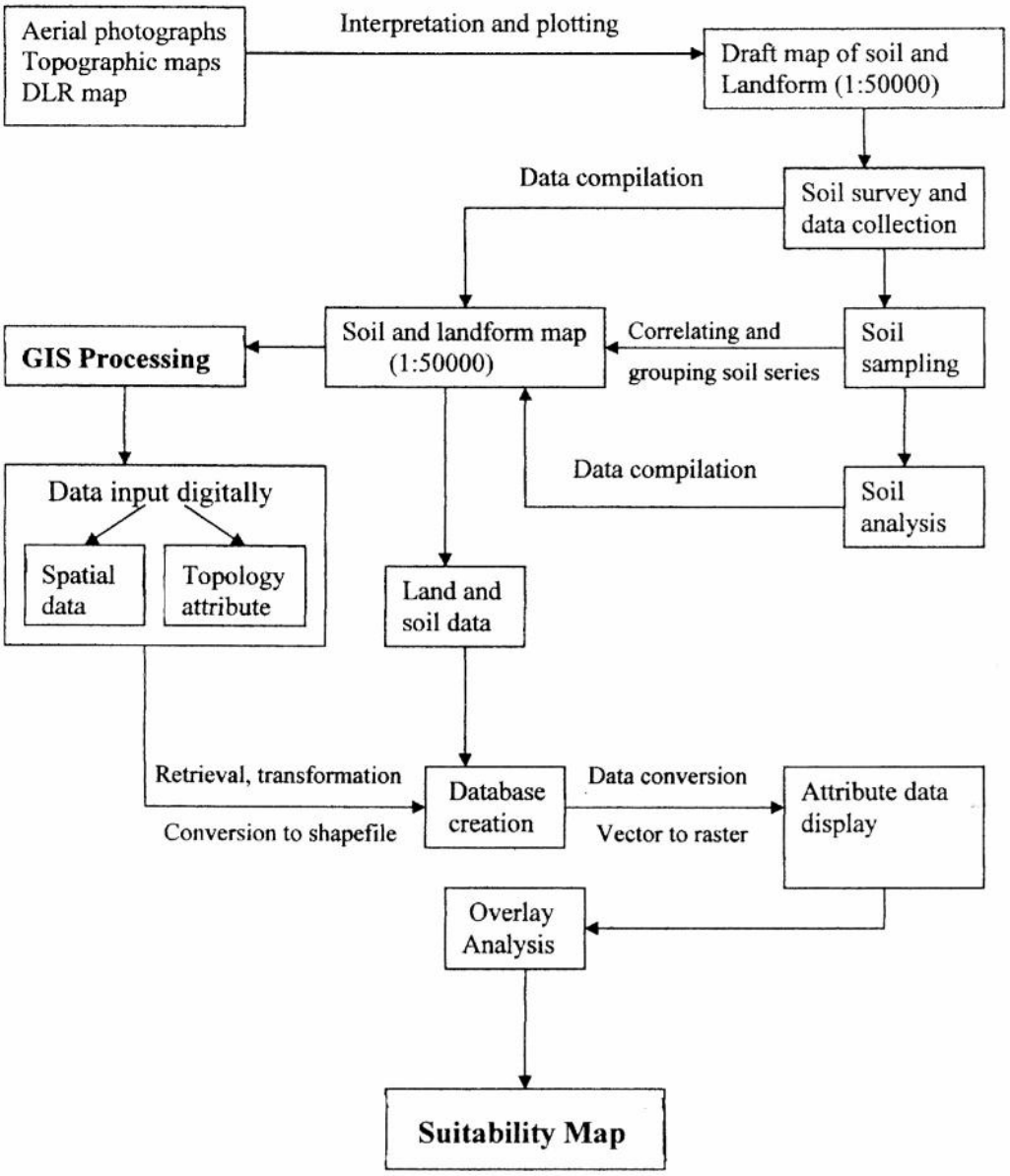
In this method, values 1, 2 and 3 were assigned correspondingly to each theme in terms of suitability scale or class, i.e. 1 for 'suitable', 2 for 'moderately suitable' and 3 for 'non suitable'. The scale was defined for attribute data or themes by considering the method of determining suitable crops based on land quality and soil characteristics as formulated in 'Land and Soil Resource Utilization Guide' published by SRDI (1990). Afterward, percent (%) influence for each theme was specified in view of 'most limiting factor' affecting wheat suitability corresponding to 'Simple Limitation Approach'. Overlay analysis was employed to generate a composite suitability map. The way with which the study was accomplished is shown in the flow-chart (Figure 3).

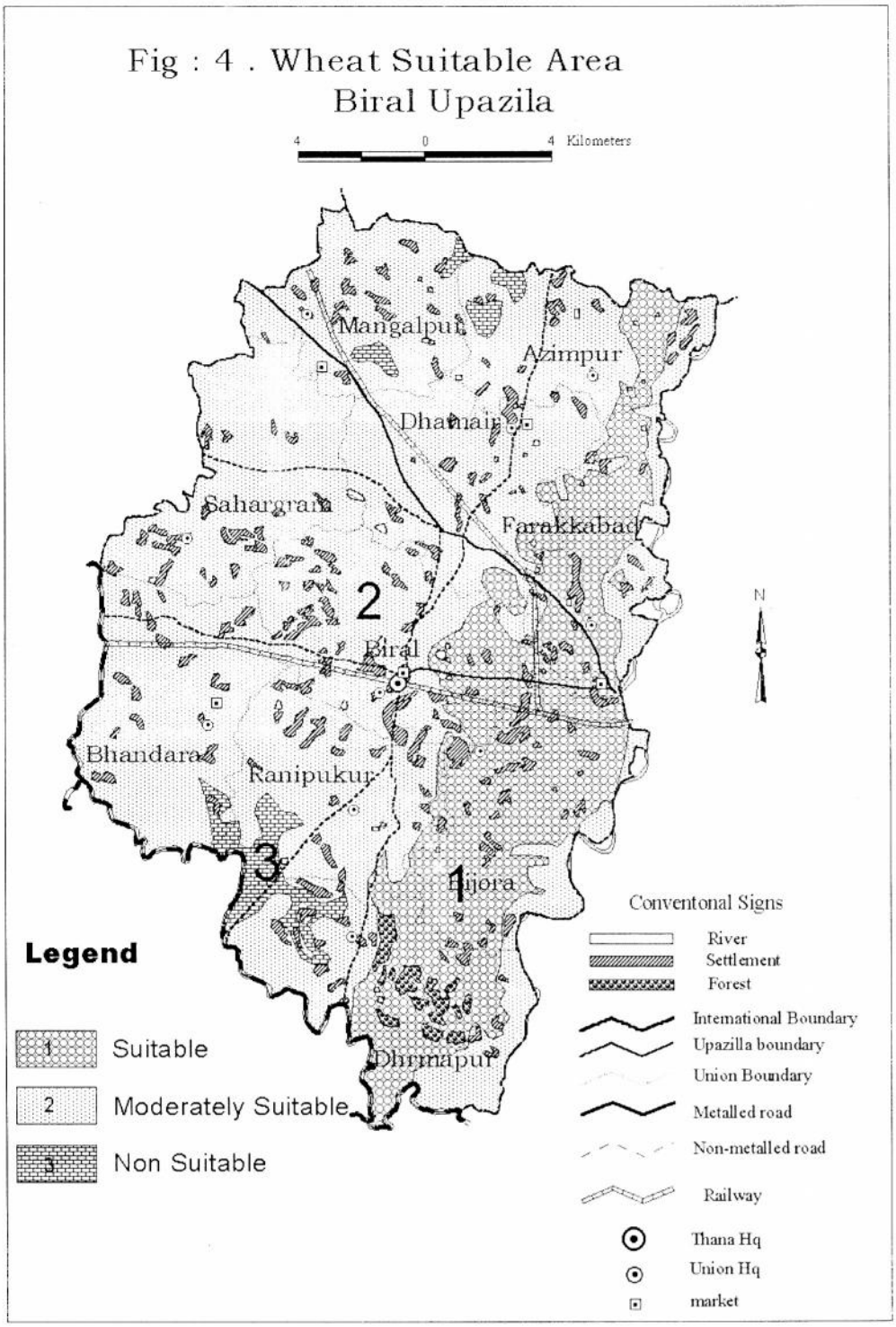
RESULTS AND DISCUSSION

The ultimate output of this study was a map (Fig.-4) depicting the variable wheat suitable area as detected by GIS based suitability assessment of agro-climate, land and soil of Biral upazila.

From this map, calculated area of about 81.75 sq. km (8,175 ha) comprising the mapping unit 1 and 2 of 'Soil and Landform Map' was found 'suitable' for wheat, while 232.43 sq. km (23, 243 ha) covering the mapping units 3 and 5 was assessed as 'moderately suitable' and only 9.81 sq. km (981ha) area comprising the mapping unit 4 was determined as 'non suitable' for wheat.

Fig. 3: Flow chart presenting the processes involved in assessing suitability of land and soil for wheat.





The 'suitable' area where soil group 'Amnura' dominating, is located in physiographic unit designated as Barind Tract. Both 'moderately suitable' area where 'Pirgacha' and 'Gangachara' are predominant soil group and 'non suitable' area in which 'Ranisankail' is the major soil are situated in physiographic unit called Himalayan Piedmont Alluvial Plain according to data compiled for analysis. Suitable land is assumed to be cultivated with no or very low inputs and expected to have >80% attainable yield of crop. Moderately suitable land is expected to have a crop yield of 60-80% 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).

Not all the factors that affect wheat production were considered but the major land and soil factors together with agro-climate were taken into account for assessing and mapping wheat suitable area. It may be assumed that suitable areas have a high potential of yield from year to year. Moderately suitable areas have limitation in production potentials only for its strongly acidic condition in 'dominant' soil. On the other hand, in non-suitable areas, undulating relief and sandy loam soil are the factors limiting wheat production under irrigated condition.

BBS (2002) reported that irrigated area in Biral at the time of agricultural census in 1996 was about 175.48 sq. km (17,548 ha) in which area under wheat and boro cultivation was 59.55 sq. km (5,955 ha) and 76.81 sq. km (7,681) ha respectively. Therefore, this is evident from the output map that there is considerable scope of bringing more area under wheat cultivation in the suitable and moderately suitable land without taking any reclamation measure.

The limitation of this analysis was that only dominant soil group in terms of its presence in major land type under individual mapping unit was considered. This was due to that delineation of area covered by different soil groups would not be possible at semi-detailed survey based soil mapping. To overcome the limitation, a cross checking was done by further GIS analysis assuming other soil as 'dominant' soil group within a mapping unit. The result was similar except mapping unit 1 which was found 'non suitable' for wheat cultivation. This was due to the presence of soil group 'Noadda' having extremely acidic soil reaction. According to soil survey data, this soil covers only 2.23 sq. km (223 ha) area (SRDI, 1985) in the mapping unit 1. Therefore, wheat suitable area in mapping unit 1 and 2 is 79.52 sq. km (7,952 ha).

CONCLUSION AND RECOMMENDATION

Although agro-environmental condition of Biral upazila was found considerably favorable for wheat production, yet two of the edaphic factors – soil reaction and irregular topography may limit wheat production in some areas. If socio-economic condition of the area accepts to undertake respective reclamation measures, then it may be possible to bring whole irrigated area under wheat production. Extension of wheat cultivation needs motivation of farmers through successful demonstration. Demonstration site should be selected in suitable land and soil as illustrated earlier. Still, it is pertinent to mention that successful demonstration is obviously dependent on present agro-environmental condition, requisite agronomic practices and balanced fertilization.

REFERENCES

Brammer, H., 1997 Agricultural Development Possibilities in Bangladesh. University Press Limited, Dhaka-1000, Bangladesh. pp. 225, 283, 341.

BBS, 2002. Census of Agriculture – 1996. Zila Series: Dinajpur. pp. 143, 192.

Clarke, K.C., 1997. Getting Started with Geographic Information Systems, Prentice Hall, Upper Saddle River, New Jersey.USA. pp. 353.

Dent, D., Young, A., 1981. Soil Survey and Land Evaluation. Allen and Unwin. London.

ESRI, 1996. Using the ArcView Spatial Analyst: Advanced Spatial Analysis Using Raster and Vector Data. Redlands, USA. pp. 26-38.

FAO. 1976. A Framework for Land Evaluation. Soils Bulletin, No. 32.

FAO/UNDP, 1988. Land Resources Appraisal of Bangladesh for Agricultural Development Report 2: Agricultural Regions of Bangladesh. pp. 119-120, 466-467.

Ghaffari, A., Lee H.C., Cook, H.P., 2000. Integrating Climate, Soil and Crop Information: A Land Suitability Study using GIS. 4th International Conference on Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs, Banff, Alberta, Canada. September 2-8, 2000.

Goodchild, M.F, 1992. Geographical Information Science, International Journal of Geographical Information Systems, Vol.6 No.1, pp. 31-45.

IRRI, 2000. Improving the productivity and sustainability of Rice-Wheat system of the Indo-Gangefic plains: A synthesis of NARS-IRRI Partnership research. Discussion Paper No 40. pp. 8.

Rossiter, D.G., 1996. A Theoretical Framework for Land Evaluation. Geoderma 72:165-190.

SRDI, 1985. Soil and Landform map (scale = 1:50000) of Biral Upazila.

SRDI, 1990. Soil & land Resources Utilization Guide: Biral Upazila, Dinajpur District. pp.1-24, 69.

SRDI, 1998. Soil and land Resources Utilization Guide: Haripur Upazila, Thakurgaon District. pp. 9

Sys Ir, C., Van Ranst E., Debaveye J., 1991. Land Evaluation Part 1 Principles in Land Evaluation and Crop Production Calculations. International training Centre for Post-Graduate Soil Scientists, University of Ghent.

Usery, E. L., Pocknee, S. and Boydell, B., 1995. Precision Farming Data Management using Environmental information Systems, Photogrammetric Engineering & Remote Sensing, 61:1383-91.