J. Himalayan Ecol. Sustian. Dev. Vol 3. (2008) **ISSN 0973-7502**

INTEGRATED ANALYSIS OF GEOMORPHIC, PEDOLOGIC AND REMOTE SENSING DATA FOR DIGITAL SOIL MAPPING

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ABSTRACT

The information about the soils is very essential for understanding a number of hydrologic, agriculture and climate processes. The study focuses on the integrated use of geomorphic, remote sensing, GIS and field pedologic observations to develop a digital soil map and attribute database. This study gains tremendous importance keeping in view the fact that no or little amount of digital soil data is available for Kashmir valley. The study was conducted in the Pulwama district of Kashmir valley having a geographical area of 1398 Sq. Kms. The datasets used for the study include satellite data (LANDSAT ETM image), Digital Elevation Model (DEM), geological map, ancillary data including various reports and publications, field data, texture and physicochemical analysis data and land use / land cover information. From the remotely sensed data, 9 soil classes were identified visually using image interpretation key based on image elements. DEM was used to generate the landform map that helped to further refine the soil classes. Texture analysis of the soil samples, collected from the field during ground truthing, was carried out to find the particle size distribution. The multi-thematic data was integrated in the GIS to generate the final soil map of the area. The final soil map represented eight soil textural classes with Silty clay-loam being the most dominant class. A database of the soil map was developed, which consisted of the physicochemical parameters and texture of the soil classes.

Keywords: Land Cover, Digital Elevation Model, Remote Sensing, Pedologic, Landscape, Geomorphology.

INTRODUCTION

Soil is one of the most important natural resources. Soil is the unconsolidated mineral matter that has been subjected to, and influenced by, genetic and environmental factors; parent material, climate, organisms and topography, all acting over a period of time.

The spatial information about the soils is essential to understand a number of land surface processes. Further, soil is a medium for plant growth, a medium for **construction** ("earth materials"), a biochemical reactor, an ecosystem, a habitat for animals and plants, a renewable natural resource, a natural resource than can be altered by man to be more suitable for specific uses, a non-renewable natural resource, an object of scientific study and a resource for recreation. Since Jammu and Kashmir lies in the Himalayan region, the major **soil** groups are submontane **soils**, hill and terai soils. The valley of Kashmir has many soil types like: Gurti (clay), Bahil (Loam), Sekil (Sand), Nambal (peats), Surzamin, Lemb, Floating-garden soils and Karewa soils.

Digital soil mapping can be defined as the creation of spatial soil information by the use of satellite images, field and laboratory analysis coupled with spatial and non-spatial soil inference systems (McBratney *et al.*, 2003). The detailed soil data is lacking for many regions of the earth and the state of Jammu and Kashmir is no exception. The main reason for the lack of soil spatial data is the costly and time taking conventional soil survey methods (McBratney *et al.*, 2003). Digital Soil Mapping (DSM) is a part

 ISSN 0973-7502

of a new emerging field of soil science known as pedometrics. Digital soil mapping makes extensive use of: (1) technological advances (e.g. use of GPS receivers, field scanners, remote sensing etc.); and (2) computational advances (e.g. geostatistical interpolation and inference algorithms, GIS, digital terrain modeling, data mining etc.). Digital soil mapping is cheaper and faster as compared to the traditional soil survey where soil boundaries are delineated manually and soil maps are typically based on the subjective interpretation by experienced soil surveyors. In case of Digital soil mapping, various semi-automated techniques and technologies are used to acquire, process and visualize information on soils together with auxiliary information, so that the end result is the spatial soil data with better accuracy at cheaper costs. Products of DSM are commonly assesed for the accuracy/uncertainty and can be more easily updated when new information becomes available. There are many advantages of DSM over the conventional soil mapping. Digital soil mapping: (1) reduces soil mapping costs, (2) produces high-resolution soil maps covering large areas, (3) offers the possibility to assess and quantify the uncertainty of the generated soil maps with an independent validation data set, (4) offers multipurpose functionality, (5) offers easy to handle information, and (6) offers easy update options.

Digitizing modern soil survey data is an essential step towards the creation of a comprehensive land information database, the backbone of an automated GIS or land information system (LIS). Once in place, such a system can greatly increase the ease with which the required soil information can be accessed and applied to land use and resource management problems.

The main objective of the present study was to develop a digital soil map and the attribute database of one of the districts of Kashmir valley. The generated information is of tremendous scientific importance.

STUDY AREA

The study area is the Pulwama district of Kashmir valley (Fig 1). The district, situated 32 Kms. from Srinagar in south Kashmir, is surrounded in the north by Srinagar, in the west by Poonch and Budgam and in the east and south by Anantnag. The total geographical area of the district is 1398 Sq. Km. The district is centrally located in the valley of Kashmir, situated between the geographical coordinates of 33°37′ – 34°06′ N latitude and 74°33′ – 75°14′ E longitude.

 ISSN 0973-7502

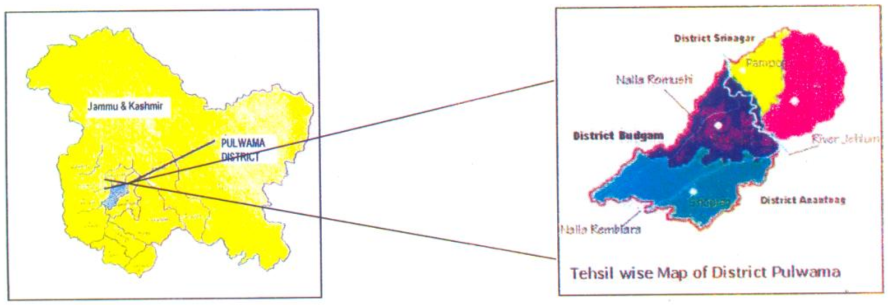

Fig. 1. Location map of the study area

DATA SOURCES

In the study, a variety of datasets from various sources including LANDSAT ETM satellite image(Fig.3), 90m digital elevation model (DEM) (Fig. 5) from Shuttle Radar Topography Mission (SRTM), landform map, geological map developed by Bhat (1989), physico-chemical analysis and texture analysis data, ancillary data including reports and publications from different agencies like NBSS & LUP, and Sher-i-Kashmir University of Agricultural Sciences and Technology (SKAUST) and ground truth data were used.

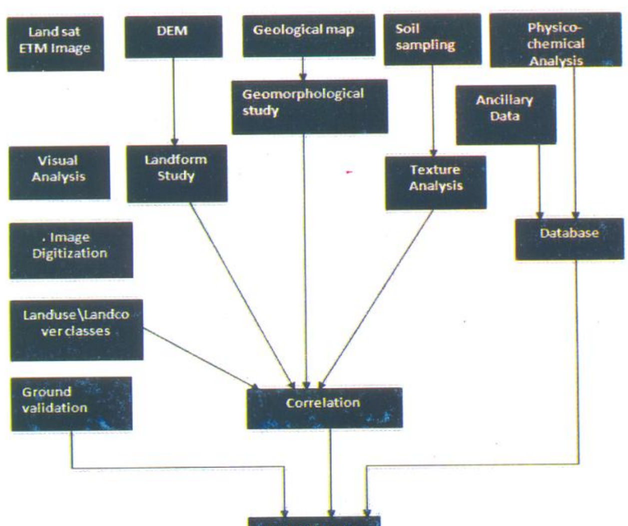

Fig. 2. Flow chart showing the methodology adopted

DATA ANALYSIS

The methodology adopted for the integration of geomorphic, pedologic and satellite remote sensing for mapping soil types in the study area is elucidated in Fig. 2. and includes the following procedures:

i. Image Processing: Before using the satellite imagery for classification of land cover types, the image was subject to a number of digital image processing techniques like co-registration, resampling, contrast enhancements etc.

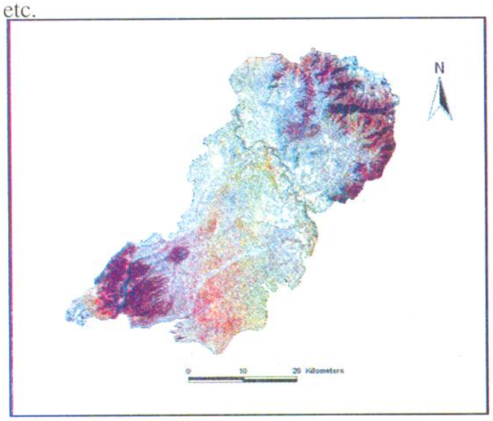

Fig3. Satellite image of Study area

ii. **Identifying and Mapping Soil Classes from the Satellite Image:** Different soil classes were identified on the Landsat Image by studying tonal variations and by incorporating the information obtained from land-use/land-cover map. Nine different soil classes were obtained after digitizing the Landsat Image (Fig. 7). Forest soil represented the maximum area i.e. 29.21% of the total study area, whereas orchard soils ranked second with 22.89% (Table 1).

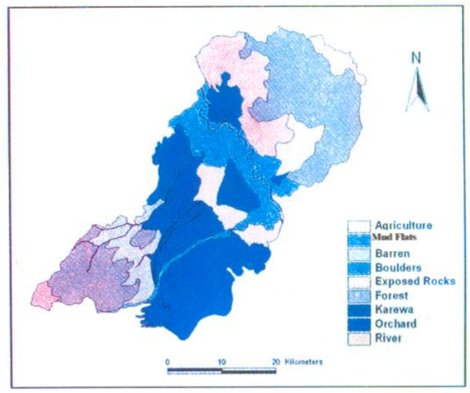

Fig 4.Map showing different Landuse\Landcover classes as digitized from satellite image

Table 1: Methodology adopted for physio-chemical analysis

S. No.	Parameter	Method
1.	pH	1:1 soil-water solution, and the reading was recorded on a digital pH meter-Model 101E (Michael, 1984)
2.	Electrical Conductivity	1:1 soil-water solution, and the reading was recorded on a digital conductivity meter (Gliessman, 1998)
3.	Loss on ignition	Muffle furnace ignition method prescribed by Hanna (1964)
4.	Exchangeable Ca / Mg	Shaking and filtration method given by Schollerberger and Simon (1945)
5.	Organic Carbon	Walkley and Black (1934) titration method

6.	Total Phosphorous	Stannous chloride method given by Bear (1964)
7.	Total K Nitrogen	Kjeldhal digestion method (Jackson, 1962)

iii. Landform Analysis

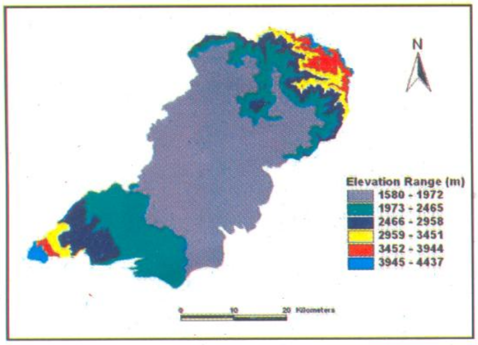

Fig.5. DEM of the study area

DEM was used for topographic analysis. The topographic analysis included generating and analyzing different themes such as altitude, aspect and slope. A landform map of the area (Fig. 6) was generated from DEM .It provided a synoptic view of the landforms which further helped in understanding the spatial variability of the soil classes. For example, plains are broad, nearly level stretches of land that have no great changes in elevation. Plain areas are found in the central parts of the district on both sides of the river Jhelum. Plains cover soils underlying alluvium, agriculture and some parts of orchards.

A plateau is a large highland area of fairly level land separated from surrounding land by steep slopes. Plateau occupies different portions of the central parts of the study area. It mainly includes the Karewa soils.

Hills are elevations of the earth's surface that have distinct summits, but are lower in elevation than mountains. Hills are found in the north-eastern and south-western parts of the study area and are almost covered entirely with forest soils. Mountains have higher elevations than the hills. . Mountains are to be found in the extreme right and left ends of the study area and include exposed rock (rock outcrop).

Little to moderate slope areas are mostly found adjacent to the Karewas and mostly bear orchard soils.

Soil landscapes recognize that soils are naturally occurring entities. They can be used to distinguish mappable areas of soils because the formation of landscapes and soils is interrelated - both have been subject to the same processes and influences over time

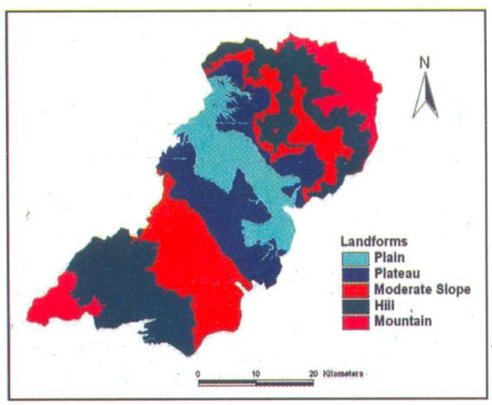

Fig. 6. Landform map of the study area

iv. Studying Geomorphology

Geomorphology of the area was broadly studied using a geological map (Fig.4). This provided information about the geology/ geomorphology of the area, further improving the delineation and the interpretation of the nature and extent of the soil classes in the study area. Soil geomorphology serves two important functions: (1) it provides basic principles for understanding the geomorphic history of landscapes (e.g., spatial and time relationships among soils, landscapes and surficial sediments); (2) geomorphic-based landscape models segregate the soil continuum into meaningful soil bodies with a minimum of effort and can explain soil distribution from local hill slope to continental scales.

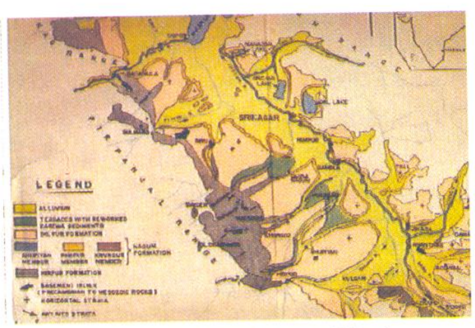

Fig 7 . Geological Map of Study area(Bhat,1989)

v. Ground Validation and Sampling

Ground validation was carried out for all the soil classes identified on the Landsat image in different parts of the study area. A portable Global Positioning System (GPS) was used to collect the accurate locations of the reference points, which were used in the validation. Soil samples were also collected during the field visits, which were then used for texture and physico-chemical analysis.

vi. Texture Analysis:

The particle size distribution is referred to as soil texture. Composite soil samples up to 15 cm depth were collected for each soil class identified by studying the tonal variations on the satellite image. Soil texture analysis was carried out by pipette method. The texture of the soil is determined from the relative proportions of sand, silt and clay that it contains. Texture analysis of the soil samples depicted a total of 8 textural classes (Table 2).

Table2. Physicochemical parameters of different soil samples

Name of the Sample	pH	Conductivity (mS)	Loss on Ignition (%)	Ca (meq/100 gm)	Mg meq/100gm	Organic Carbon (%)	Organic Matter (%)	Inorganic Phosphorus (mg/lt)	Organic Phosphorus (mg/lt)	Total K Nitrogen (mg/gm)
Orchard	7.14	0.64	6.4	3.76	1.04	1.20	2.06	0.74	0.21	0.33
Karewa	6.39	0.60	5.4	2.90	0.82	0.60	1.03	0.31	0.51	0.23
Mud Flats	7.21	0.50	3.6	2.28	0.94	1.47	2.53	0.59	0.22	0.27
Plantation	6.67	0.46	9.4	3.24	1.96	0.36	0.62	1.01	0.10	0.36
Forest	5.50	0.41	17.2	5.18	2.54	5.13	8.84	0.47	0.61	0.47
Barren	5.80	0.40	6.0	2.56	1.12	2.70	4.65	0.56	0.65	0.42
Urban	7.00	0.39	9.6	7.0	0.74	1.92	3.31	0.56	0 06	0.19
Agriculture	6.10	0.44	6.8	3.3	1.20	1.98	3.41	0.50	0.68	0.45
Meadow	6.34	0.48	10.0	4.92	0.28	3.48	5.99	0.51	0.53	0.28

vii. Physicochemical Analysis

Physicochemical analysis of the soil samples was carried out in order to generate the database of the final soil map. Standard methodology was followed for the analysis (Table 3).

Table 3: Methodology adopted for physico-chemical analysis

S. No.	Parameter	Method
1.	pH	1:1 soil-water solution, and the reading was recorded on a digital pH meter-Model 101E (Michael, 1984)
2.	Electrical Conductivity	1:1 soil-water solution, and the reading was recorded on a digital conductivity meter (Gliessman, 1998)
3.	Loss on ignition	Muffle furnace ignition method prescribed by Hanna (1964)
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5.	Organic Carbon	Walkley and Black (1934) titration method
6.	Total Phosphorous	Stannous chloride method given by Bear (1964)
7.	Total K Nitrogen	Kjeldhal digestion method (Jackson, 1962)

Physico-chemical analysis of the soil samples provided an insight into the nutrient status of different soil types present in the area. The parameters varied from one soil type to another.

RESULTS AND DISCUSSION

A digital soil map was generated as a final step. Since this study employs geospatial tools to identify and map the soil classes, the soil map digitized from the satellite image was corrected using geological map, landform map and the texture data. Land use/land cover Information was also used to refine the boundaries and extents of the soil classes. The final map was developed at a scale of 1:50,000. A database/attribute information was attached to the final digital soil map based on the results of the texture analysis and physico-chemical analysis. The Fig. 8 shows the digital soil map of the Pulwama district and depicts 8 soil classes.

The digital soil map, thus generated, was validated in the field for verifying the extent and the boundaries of the soil classes. The geologic, hydrographic, land cover, landform and other ancillary information was used to improve the accuracy of the digital soil map.

The database of the soil map was prepared in a GIS environment and comprises of standard soil nomenclature, textural information and the physio-chemical attributes of each soil group. The pH values recorded at all the sites except orchard indicate that the soils are slightly acidic in nature, as the recorded values for pH are an indication of a higher nutrient status especially in the top layer. Jones *et al.* (2002) related the acidic value of soils to the higher rate of leaching and very high percentage of organic matter in the soils. The measurement of electrical conductivity is directly related to the soluble salt concentration. Electrical conductivity shows a decreasing trend with an increase in altitude, which may be attributed to the leaching of soluble salts from higher altitudes.

Exchangeable calcium and magnesium were recorded to be highest in forest soils, as their uptake greatly exceeds annual requirement from both the deciduous and coniferous forest species indicating that magnesium accumulates in the older tissues of the trees. Exchangeable magnesium content is in the range of 0.28 – 2.54 meq/100gm, which may be due to the presence of chlorite and degraded illites in these soils. The presence of illite which is known to have Mg2+ within brusite layer has been reported to be most dominant mineral in J&K soils (Gupta *et al.,* 1977).

The higher content of organic matter in forest soils is due to forest vegetation and low mineralization due to low temperature that slows down the decomposition of organic matter by restricting the microbial population. This is supported by Talib (1983) and Nakashgir *et al.* (1997).

Since soil structure and soil hydrology are directly linked to the texture, the soil texture thus determines the existence of various land features / land use classes on a landscape. Texture analysis of the soil samples depicted a total of 8 textural classes (Table 3) viz. silt-loam, loam-silt loam, silt loam-loamy, silty clay-loam, loamy, sandy loam, clay loam and rock outcrop.

Soil texture varies for different land features and land use classes as depicted in the results of this study. Forest soil has sandy loam texture, orchard soil has silt-loam, karewa, soils under barren including degraded forest, agriculture, alluvium, plantation and exposed rock have loam-silt loam, silt clay-loam, silt loam-loamy, loamy, clay loam and rock outcrop texture respectively.

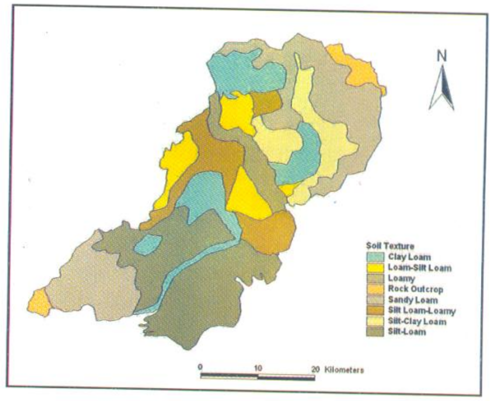

Fig 8. Digital soil map of Pulwama

Table 4. Area-wise distribution of soil classes in the final soil map

S. No.	Soil Class	Area (Km^2)	% of the total area
1.	Silt Loam-Loamy	161.02	10.88
2.	Loamy	68.04	4.60
3.	Loam-Silt Loam	116.74	7.89
4.	Clay Loam	208.17	14.07
5.	Silt-Loam	368.95	24.94
6.	Silt-Clay Loam	128.94	8.71
7.	Sandy Loam	382.79	25.87
8.	Rock Outcrop	44.48	3.00

Table 5. Physicochemical parameters of different soil samples

Name of the	pH	Conductivity (mS)	Loss on Ignition (%)	Ca (meq/100 gm)	Mg meq/100gm	Organic Carbon (%)	Organic Matter (%)	Inorganic Phosphorus (mg/lt)	Organic Phosphorus (mg/lt)	Total K Nitrogen (mg/gm)
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Meadow	6.34	0.48	10.0	4.92	0.28	3.48	5.99	0.51	0.53	0.28

CONCLUSIONS

The digital soil map of the district was developed from the analysis of remote sensing data supported with detailed field and laboratory analysis. Eight soil types were delineated in the study area. The boundaries of the soil classes were corrected using landform map, geological map and other ancillary data. A database was also attached to the soil map. The database contains information about the physicochemical parameters and particle size distribution (texture) of the soil classes.The digital soil map generated here shall be useful

for a number of applications in hydrology, agriculture, forestry and other scientific studies. Further, the database facilitates the easy availability of information to the planners and land resource managers for planning and management of soil resources in the district.

ACKNOWLEDGEMENTS

This paper forms a part of the P.G.Diploma project work of the first author carried out at the P.G.Department of Geology and Geophysics.The authors are highly thankful to the Head, P.G. Department of Environmental Sciences, University of Kashmir for providing laboratory facilities.

REFERENCES

Bear, F. E. 1964. Chemistry of the Soil. Reinhold, New York.

Bhat, D. K. 1989. Litho-stratigraphy of Karewa group, Kashmir, India and a critical review of the fossil records. Geological Survey of India Momoirs. Vol. **122**.

Gliessman, R. S. 1998. Field and laboratory investigations in Agro-ecology. University of California, Santacruz Lames Publishers, U.S.A.

Gupta, R. D., Jha, K. K. and Sahi, B. P. 1977. Mineralogical studies of the clays of J&K. Journal of Agriculture Chemistry. **10**(1 & 2):177.

Hanna, W. J. 1964. Methods for chemical analysis of soils. In: Chemistry of the Soil (Fireman Bear, ed.). Oxford and IBH Pub. Comp.

Jackson, M. L. 1962. Soil Chemical Analysis. Constable Co. Ltd., London.

Jackson, M. L. 1975. Soil Chemical Analysis – Advanced Course. Dept. of Soils, University of Wisconsin, Madison, WI.

Jones, C. A., Jacobsen, J. and Lorbeer, S. 2002. Metal concentrations in three Montana soils following 20 years of fertilization and cropping. Commun. Soil Sci. Plant Anal. **33** (9 & 10): 141414.

McBratney, A. B., Santos, M. L. M. and Minasny, B. 2003. On digital soil mapping. Geoderma. **117**(1-2): 3-52.

Michael, P. 1984. Ecological Methods for Field and Laboratory Investigations. Tata McGraw Hill Pub. Comp. Ltd.

Nakashgir, G. H., Peer, G. H., Rafique, M. M. and Arora, C. L. 1997. Critical limits of potassium for rice in soils of Kashmir valley as influenced by altitude of the region. Journal of Potassium Research. **13**(3 & 4): 249-256.

Retallack , G. J., Dugas, D. P. and Bestland, E. A. 1990. Fossil Soils and Grasses of a Middle Miocene East African Grassland. Science. **247**: 1325-1328.

Schollerberger, C. J. and Simon, **R**, H. 1945. Determination of exchange capacity and exchangeable bases in soil ammonium acetate method. Soil Science. **59**: 13-24.

Talib, A. R. 1983. Studies on the pedogenesis and potassium supplying capacity of the benchmark soils of Kashmir. Ph.D. thesis, Himachal Pradesh Krishi Vishva Vidyalaya,Palampore, (H.P).