Module 3.6

Remote Sensing (RS) and Geographical Information System (GIS) Applications at Watershed, National, Regional and Global Levels

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Objectives

- To present the application of RS/GIS at a micro-watershed level
- To describe applications of RS/GIS at national, regional and global levels
- To discuss the advantages and limitations with some recommendations

How can remote sensing (RS) and geographical information systems (GIS) be used for PIWM?

Remote sensing (RS) and geographical information systems (GIS) can be applied at all levels of area coverage and presentation. Application at the watershed level is most common, but RS and GIS applications at national, regional and global levels are also possible.

Although GIS methodologies are highly technical, communities can participate in preparatory work when information is gathered and when the results of the analysis are used for decision-making. In India, the Indian Remote Sensing (IRS) satellite data have been applied through an integrated approach in the National Natural Resources Management System (NNRMS) and Integrated Mission for Sustainable Development (IMSD). These applications involved integration of various central and state agencies/departments. The Indian National Satellite (INSAT) facilitates communication applications that include radio and television networking, weather forecasting and education services. Through the INSAT satellite, it is possible for remote farmers to be educated and even for TV interaction between farmers and professionals in towns. GIS maps have assisted farmers in planning agroforestry activities and developing village forest management plans. With these approaches community participation can be achieved.

What types of application are possible using RS and GIS?

- Land-use and land cover analysis
- Land-use changes over time
- Town planning applications
- Forestry planning applications
- Hazards and landslide analysis
- Environmental impact analysis
- Disaster warning and remedy operations

GIS applications at the watershed level (Shivapuri Watershed, Kathmandu, Nepal)

GIS has been used in the Shivapuri watershed for

- preparation of maps of land-use change between 1981 and 1993,
- assessment of major land-use categories,
- estimation of the extent of land-use changes in agriculture, forestry and non-forest lands, and
- establishment of land capability criteria for proposing the land capability map and land-use adjustment map.

For carrying out the above tasks, base maps of the Shivapuri Watershed were first prepared. A topographic map from the Indian Survey of 1950 with 1' to 1 mile scale and the maps prepared by E. Schneider with 1971 aerial photographs on a scale of 1:10,000 scale were used for preparing the base maps. Aerial photographs from 1981, 1989 and 1991 were used for interpretation of land use. After field checks, the land-use information was put on to base maps. 1981 and 1993 land-use maps were prepared. These land-use maps were digitised to ente them into the GIS computer for analysis and mapping.

Land-use changes in the watershed have been analysed and tabulated (Table 1). Changes are given as reduc-

Table 1: Land use in Shivapuri Watershed for 1981 and 1993 and changes

Land Use	1981		1993		Changes	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	7668.8	36.16	7477.0	35.26	-191.8	-0.90
Forest	7771.4	36.65	8638.3	40.74	+866.9	+4.09
Shrubs	3412.2	16.09	3148.2	14.85	-264.0	-1.24
Grassland	1032.3	4.87	618.9	2.92	-413.4	-1.95
Grassland with shrubs	850.8	4.01	555.6	2.62	-295.2	-1.39
Landslides	87.3	0.41	102.3	0.48	+15.0	+0.07
Settlements	166.6	0.79	187.6	0.88	+21.0	+0.09
Riverine features	22.9	0.11	45.7	0.22	+22.8	+0.11
Abandoned lands	191.9	0.91	430.6	2.03	+238.7	+1.12
Total	21204.2	100	21204.2	100		

Source : Karim and Tamrakar 1994

tions in agricultural land and increases in forest. These changes are also shown on the map.

More detailed analysis of land-use categories can be carried out. The change in various forest types and shrubland in 1981 and 1993 indicated the actual changes observed (Table 2).There was an increase of 700 ha of hardwood and 180 ha of conifers.

Once the database is in the GIS, further analyses can be made. One example is analysing slope to determine land capability for agriculture, forestry or fodder and grazing lands.

Applications of GIS at the national level

GIS applications for flood control in Bangladesh

Flood control is important in Bangladesh as frequent floods occur and have devastating effects on human life, agriculture, industry and infrastructure. Entire flood control which is impracticable, but systems can be built for flood damage reduction. Rainfall in Bangladesh is high and flooding is serious. International assistance was requested to develop a flood action plan (FAP) to identify and prepare structural and non-structural flood control and water management plans. Mathematical models are used to predict the hydraulic behavior of the river systems. Models using one dimension are used for predicting river flow and two dimensions are used for flood-plain flow predictions. The main objective of the FAP is 'to protect people's lives, houses, commercial and industrial centres' (Paudyal and Syme 1994). To achieve the objective of the FAP, computer-based mathematical models of the Brahmaputra, Ganges and Meghna rivers were developed. MIKE11 software (a one-dimensional hydraulic model) provides simulation for flows, water quality, and sediment transport in rivers as well as irrigation systems, channels and other water bodies but it has no capability for spatial presentation of data. It was necessary to link the hydraulic model with a GIS to build a spatial decision support system (SDSS). A PC/ARCINFO workstation software was linked with MIKE11 software and the simulation results for hydraulic characteristics were spatially presented and analysed in GIS. This was the basis for developing the Flood Plain Management Model. GIS outputs were used to estimate the flooded area duration, depth, and extent and for frequency mapping of floods. In combination with other data, such as crop-planting data, land-use data, soil-association map data and return-period data, it was possible to assess flood damage. The indirect costs could also be calculated. Thus environmental and social impacts were also assessed.

Table 2 : Changes in various forest types between 1981 and 1993

Land Use	1981		1993	
	Area (ha)	%	Area (ha)	%
Mixed Forest	94.0	0.84	45.1	0.38
Hardwood Forest	7207.4	64.45	7934.1	67.32
Coniferous Forest	470.0	4.20	659.1	5.59
Shrubs/ Scrub	3412.2	30.51	3148.2	26.71
Total Forest Area	11183.6	100	11786.5	100

Source : Karim and Tamrakar 1994

Data associated with the GIS are flood data, such as flood depth, area, and duration; socioeconomic data, such as demography, employment, social status, and education; environmental data on fisheries, wetlands, habitats, forestry (mangrove), ecology, pollution, surface water, a groundwater, forests, and fuelwood use; data on infrastructure agriculture and livestock. During floods ground survey may not be possible so remotely sensed data may be applied and digitised for GIS (Paudyal and Syme 1994).

Constraints include

- need for MIKE11 and other systems including hardware and software,
- need to link different systems,
- collection of data for analysis during flood period needs a lot of effort,
- financial necessities, and
- manpower required.

Opportunities include

- can assist flood control,
- flood damage can be reduced,
- planning for the after-flood period can be facilitated,
- the database will be useful for studies and future analyses, and
- cost and speed are reasonable.

RS/GIS applications to construct a land-use map for Myanmar

A land-use map for Myanmar was prepared using Landsat TM imagery for 1989 (Tint et al. 1991). (Table 3).

In the analysis the following land-use categories were identified

- closed forests,
- closed forests affected by shifting cultivation,
- degraded forests,
- degraded forests affected by shifting cultivation,
- non-forest areas including agricultural land, settlements, etc, and
- water bodies.

In identifying the various land-use types existing, aerial photographs were also used. The resulting land-use map was used to determine forest cover changes by comparing them with the land-use map of 1979 (Tint and Hla 1991).

Constraints include

- Landsat TM satellite data are expensive,
- gathering digitising data of state and division boundaries is time consuming, and
- the absence of digital imagery of Landsat data and software for analysing imagery, such as ERDAS (Earth Resources' Data Analysis Systems)

Table 3: Land-use table by states and divisions of Myanmar (sq. km.)

State / Division	Closed forest	Degraded forest	Forest with shifting cultivation	Non-forest	Water body	Total
Kachin	72718	2292	8119	5147	763	89039
Kayah	3536	1606	4165	2345	79	11731
Kayin	12155	1068	11080	5897	182	30382
Chin	17640	882	17062	419	14	36017
Sagaing	56950	7157	5163	24201	1150	94621
Tanintharyi	33755	1083	5637	2112	756	43343
Bago	14473	1274	5594	16914	1148	39403
Magway	4864	6884	15433	16205	1433	44819
Mandalay	6630	4303	6611	18710	768	37022
Mon	2739	1130	2804	5032	591	12296
Rakhine	20059	1881	3482	8980	2375	36777
Yangon	1164	145	478	7998	386	10171
Shan	41679	18335	66896	27991	895	155796
Ayeyarwady	4907	2928	1865	22649	2787	35136
Myanmar	293269	50968	154389	164600	13327	676553

makes manual interpretation unavoidable; transferring data into the system is time consuming.

Opportunities include

- state or division analysis is possible,
- the Himalayan region of Myanmar can be easily separated for different studies,
- the land-use map of Myanmar can be published, and
- comparison with previous land-use data is possible for forest degradation rates.

Application of RS/GIS at the regional level

An application has been designed for studying the forest cover of key Asian watersheds; these include the following river basins: Indus, Ganges, Brahmaputra, Mekong, Yangtze, and Yellow river. Estimating forest cover in a few months is not possible by any means other than remote sensing. In this study, NOAA AVHRR satellite imagery for 1992-93 (Loveland et al. 1997) was applied. Satellite data were available for the whole Asia and Pacific region and the study watersheds need to be separated by GIS. The following activities were carried out.

- Key Asian watersheds were identified by differentiating drainage on the world digital chart on a scale of 1:1,000,000.
- Land-use data for each key Asian watersheds with GIS were generated (Table 4).
- Elevation data for each key Asian watersheds were generated (Table 5).

Constraints include

- need for NOAA AVHRR data,
- need for a digital chart of the world,
- need for field checking: the land-use data had to be cross checked with the land-use map of Myanmar

Table 4: Land cover for six key watersheds in Asia and the Pacific

Sr. No.	Land cover type	River Basin (Area in percentages) Yangtze	Yellow	Indus	Ganges	Brahmaputra	Mekong	Total
1	Evergreen needleleaved forest	0.05	0.01	0.03		0.02	0.01	0.02
2	Evergreen broadleaved forest	0.22	0.24	0.02	0.57	2.09	18.42	2.86
3	Deciduous needleleaved forest	0.19	1.82					0.30
4	Deciduous broadleaved forest	6.49		0.37	7.63	11.64	14.36	6.41
5	Mixed forest	1.46	0.88	0.12	0.17	0.76	11.23	2.18
6	Closed shrublands	2.38	0.02	2.24	1.93	0.12	3.03	1.83
7	Open shrublands	0.99	20.08	27.22	1.63	8.90	0.84	8.54
8	Woody savannah	0.94	0.16	0.23	0.01	0.66	4.17	0.96
9	Grasslands	20.80	41.92	16.24	6.59	44.00	10.38	21.25
10	Permanent wetlands	0.17	0.01	0.11		0.05	0.02	0.08
11	Croplands (agricultural lands)	41.04	15.51	35.20	67.61	13.72	31.60	37.48
12	Urban built-up areas	0.11	0.11	0.12	0.18	0.02	0.04	0.11
13	Croplands/natural vegetation mosaic	23.05	12.36	2.31	9.92	12.86	4.32	12.56
14	Snow and ice			3.24	0.88	1.09		0.77
15	Barren/ sparsely vegetated	0.26	5.73	11.36	1.58	2.27	0.03	3.14
16	Water bodies	1.84	1.17	1.17	1.30	1.79	1.55	1.51
	Total	100	100	100	100	100	100	100

Source : Myint and Hofer 1998

Table 5: Elevation zones for six key watersheds in Asia and the Pacific

Sr. No	Elevation Zone (m)	River Basin (Area in thousand sq. km.) Yangtze		Yellow		Indus		Ganges		Brahmaputra		Mekong		Total	
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1	0 – 300	603.8	33.39	56.0	7.06	330.3	34.97	510.0	48.58	108.92	18.7	250.1	31.47	1,859	31.14
2	300 - 1,000	418.1	23.12	61.5	7.75	95.9	10.16	113.5	10.81	34.22	5.90	290.8	36.58	1,014	16.98
3	1,000 - 2,300	290.2	16.05	467.0	58.8	135.5	14.35	70.88	6.75	43.15	7.44	136.4	17.16	1,143	19.14
4	2,300 - 3.600	119.7	6.62	77.1	9.71	85.30	9.03	33.81	3.22	30.86	5.32	20.43	2.57	367	6.15
5	Above 3,600	338.9	18.74	132.2	16.6	263.3	27.88	82.74	7.88	315.23	54.3	93.65	11.78	1,226	20.53
6	No data	37.4	2.07	0.00		34.10	3.61	238.9	22.76	47.68	8.22	0.32	0.04	358	6.00
	Total	1,809	100	794	100	945	100	1,050	100	580	100	795	100	5,972	100

Source : Myint and Hofer 1998

(comparison indicates the reliability of the land-use interpretation).

Opportunities include;

- forest cover estimates are available within the time permitted,
- regional as well as watershed level analysis is possible, and
- representative maps are produced.

RS/GIS applications at the global level

RS and GIS applications at the global level can also be formulated. For a good example of global applications refer to the training material on RS/GIS applications entitled, *Remote Sensing for Environmental Impact Assessment,* by S. Murai (1994). The NOAA AVHRR satellite data and other global data sets including temperature, precipitation, soil, and elevation are applied for assessing global forest cover and potential areas for forest cover. With the analysis, global planning is proposed. For this exercise the following tasks are involved.

Preparation of actual vegetation maps with a global vegetation index of eight types.

- Tropical forests
- Evergreen forests
- Deciduous forests
- Tundra
- Agriculture and grassland
- Semi-desert
- Alpine-desert
- Desert

Preparation of potential vegetation against global data sets of the following.

- Arid or moisture index
- Temperature
- Precipitation
- Elevation

Assessment of changes in vegetation cover (Table 6).

- GIS was applied using global data for predicting the suitability of forest conservation and reforestation.
- The global map for forest conservation was prepared indicating the 'very high' and 'high' land suitability of forested areas.
- The global map for reforestation was also prepared showing the 'high' and 'low' land suitability for reforestation in non-forest areas.
- The exercise demonstrated that RS/GIS applications are powerful tools for global environment monitoring as well as global planning.
- Use of RS/GIS is helpful for planning the sustainable use of the earth's resources.

Constraints include

- need for global data sets, and
- need for technical know-how
- Applications needs global collaboration cannot be at the watershed level.

Opportunities include

- global analysis of environmental monitoring is possible,
- analysis can be done in a short time,
- the cost is reasonable, and low for global coverage, and
- policy-level strategic planning can be exercised.

Advantages in and limitations to using GIS

GIS are efficient because spatial data once stored in the computer system can be retrieved and used for analysis.

Table 6: Change in vegetation cover due to human interference (unit %)

	Tropical forests	Other forests	Grassland	Semi-desert	Desert	Total
Potential vegetation	13.4	35.9	28.7	10.6	11.4	100.0
Actual vegetation	5.9	28.1	33.9	14.9	17.2	100.0
Difference	-7.5	-7.8	+5.2	+4.3	+5.8	0.0
	-15.3	Deforestation	+5.2	+10.1	Desertification	0.0

Source : Murai (1994), Shunji Murai, Global Engineering Project for Sustainable Use of the Earth, Technical Report to the UN COPUOS, June 1993

Information is easy to update and the whole process does not need repeating, unlike in manual systems. Comparison of changes is possible for a series of data. GIS applications are fast and accurate. Maps can be produced for many alternatives and repeated with great accuracy. Presentations of GIS maps are of major value and the scale of the maps becomes flexible.

Advantages can be summarised as

- speed,
- accuracy,
- efficiency,
- repetition and duplication is possible,
- complicate analysis is possible,
- better presentations, and
- flexibility in mapping.

Limitations of GIS applications are the need for special hardware and software, technical know-how, and skills for operating the system. Some investment in these has to be considered. Remote-sensing data are costly and sometimes interpretation is difficult. Participation of the community in implementing GIS is not easy; it is only possible in data gathering and use of the results. Proper maintenance of the system and a regular supply of stationery can also become limitations in some circumstances.

Limitations are

- need for special hardware and software,
- need for trained persons for operation and analysis,
- involvement of some investment,
- community participation is difficult,
- satellite data or remote-sensing data can be expensive, and
- poverty being the root of most problems and development being the main solution, this high-tech application may not be in the interests of the community.

Conclusion and recommendations

It is important that the community is aware of the environment and the impacts of development. Rapid and accurate results using modern technologies can be helpful. RS/GIS data can yield strategic information, such as forest cover and land-use changes, within a reasonably short period of time. RS/GIS application can be used for community-based and global planning. It involves the following main activities.

- Setting of clear objectives for using RS/GIS
- Design of the application
- Collection of material
- Preparation of data
- Analysis
- Interpretation of the results
- Reporting

References and further reading (not necessarily cited in the text)

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