Geo-Informatics for National Development Planning: Experience of Bhutan

Dr. Moe Myint, Chief Scientist, Mapping and Natural Resources Information Integration (MNRII), Switzerland
Mr. Arun Rai, Senior Forestry Officer, Forest Resources Management Division (FRMD), Bhutan

KEY WORDS: Forest, Conservation, Ecosystems, Watersheds, Population, Hydropower

Abstract

The Geographic Information System, Remote Sensing Technology, Global Positional System, Spatial Databases, Resource Economics and Applied Statistics have played important roles for the National Development Planning for Bhutan. Geo-informatics has been introduced since 1993 for Land Use Planning of Bhutan. Bhutan has successfully applied Geo-Informatics for National land use planning, population and housing census reporting, watershed management for hydropower generation, conservation planning of protected areas and biological corridors, designing the national forest inventory system, forest resources potential assessment and valuation for payment of environmental services. This paper will describe and share the experience how the Geo-Informatics technology has been successfully applied and shape the information landscape of Bhutan for National Development Planning since 1993 to present.

Introduction of Geo-Informatics in Bhutan

Bhutan is peaceful Himalaya kingdom which facilitates her people living in harmony with natural environment, Buddhist philosophy and traditional cultural values. Bhutan is mountainous landlocked country with abundant water resources, forest resources and rich biological diversity across the moderately inaccessible geologically fragile landscapes of Himalaya.

Sustainable land management and fair share of values and benefits from resource utilization and maintenance of ecosystem services to the community and industry is fundamental for national development planning. Bhutan introduced the Geo-Informatics in 1993 in order to establish a sound digital spatial database which was accessible and share to government and non-government organizations for the national development planning.

At an early stage of Geo-Informatics technology introduction to the Nation, Bhutan realized an important understanding of the limitations of technology and the role of errors in data collection, conceptualization, analyses and presentation on the perceptions of results for natural resources management and planning for development.

Important Indicator of Ecosystem functions for National Development Planning

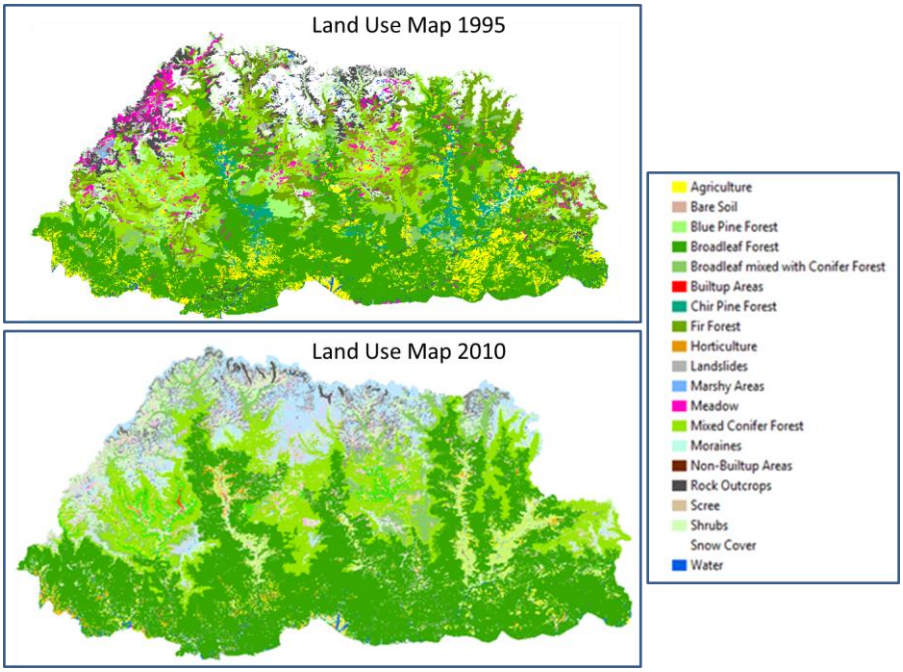
Constitution of Bhutan clearly indicates to maintain 60% of forests cover all the time. It insures that the ecosystem function at the landscape through maintenance of vegetation cover which will conserve the biological diversity and produce the sustained water yield throughout the year. Monitoring the forest cover, water yield of major watersheds and biological diversity is an essential and integral component of development planning activities. The development activities should compensate the loss of forest vegetation cover which negatively impacts the ecosystem services.

Available Spatial Data for National Development Planning prior to 1993

Prior to 1993, the 1:50,000 scale topographic sheets (paper format) produced by the Indian Survey were the best spatial data sources for National Development Planning. There are total 81 topographic sheets with Polyconic Map Projection System. The geodetic parameters were Everest 1956 Spheroid and Datum which were obsolete today. The second editions of these maps were published in 1967 under the direction of Surveyor General of India.

First Geo-Informatics Project of Bhutan

In 1993, Policy and Planning Division (PPD) of Ministry of Agriculture (MoA) initiated Land Use Planning Project (LUPP) which created the first digital spatial database of administrative boundaries (Dzongkhags and Gewogs), roads, drainages, contour lines and settlements by digitizing the topographic sheets. The digital spatial database was created using PC Arc/Info based on Polyconic Map Projection System with Everest 1956 Datum and Spheroid.



The first map describes the first land use working map (1995) of Bhutan.

The LUPP project produced the first land use working map by intensive field visits and detail visual interpretation of Panchromatic SPOT Satellite Images (10 meter spatial resolution) at 1:50000 scale in 1997. The interpreted results were digitized in order to create the digital land use database. Important contribution of the LUPP project was in establishing a sound digital spatial database. For the first time, Bhutan had a very good database of spatial information which was shared with many other agencies and it indeed contributed modern method of planning and assessing land uses. The LUPP project collected lots of soil samples, established soil laboratory and made concrete contribution to soil conservation.

At the end of the project 2002, it left behind a group of confident staffs and first spatial database for development planning. Synergies of the first geo-informatics built the capacity of individuals who continue to create important ad valuable spatial databases of Bhutan such as glacier lakes, snow cover, geology, geomorphology, soil resources, electrical power lines, roads and footpaths of the country.

Land use and land cover updating and mapping 2010

The first land use working map (1995) by the LUPP project was long overdue and the need for the update was vital. The ALOS – AVNIR-2 multispectral images were selected for updating the land cover because of its 10 Meter spatial resolution. Moreover, the 10 Meter resolution land use data is suitable for local and national level spatial planning and analyses.

The land cover map (1995) was updated through digital image processing of multi-spectral ALOS images (AVNIR-2) from the 2006-2009 winter seasons, combined with other reference materials and extensive ground truthing exercises. Image segmentation and Multinomial Logistics Regression was applied for image classification using Erdas Imagine and R Statistics. In order to ensure a reasonable level of precision, a system accuracy assessment was carried out by comparing randomly selected referenced pixels. An overall acceptance level of map accuracy was set at 85%. The second map describes the updated land use map (2010) of Bhutan.

The updated land use and land cover (LCMP 2010 – Land Cover Assessment Project 2010) shows a national forest cover of 70.46%, of which 62.43% is broadleaf, 22.69% is mixed conifer, 6.77% is fir, 3.98% is chir pine, 2.96% is blue pine and 1.16% is broadleaf with conifer. The shrubs constitute 10.81%, while cultivated agricultural land and meadows account for 2.93% and 4.10% respectively. The snow cover constitutes 7.44% while bare areas constitute 3.20%. Degraded areas, water bodies, built up areas, marshy areas and non-built up areas constitute less than 1% each. Within the 2.93% of cultivated agricultural land, *Kamzhing (dry land agriculture)* dominates with 61.90% followed by *Chhuzhing (wet land agriculture)* with 27.86% and horticulture land with 10.24%.

Geographic Framework of Bhutan: Drukref Datum

Bhutan created new coordinate system called DrukRef - based on Transverse Mercator system using GRD80 Datum and GRS80 Spheroid. The DrukRef project developed a standard coordinate system and Geographic Framework for Bhutan to substitute obsolete 1956 Everest Datum and Spheroid.

National Cadastral Survey was follow up for 5 years project (2008-2013 in order to create the detail Geodatabase on actual land holding size of Bhutanese people based on the new Geographic Framework of the Nation.

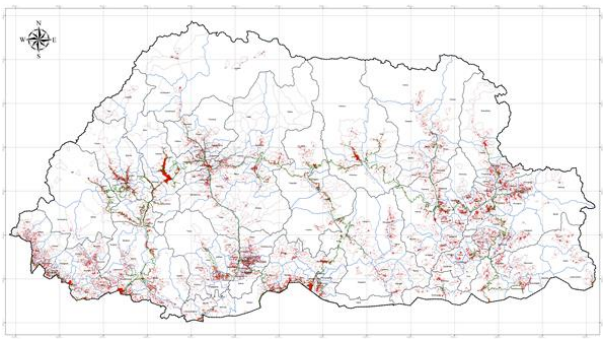
Population and Housing Census of Bhutan 2005

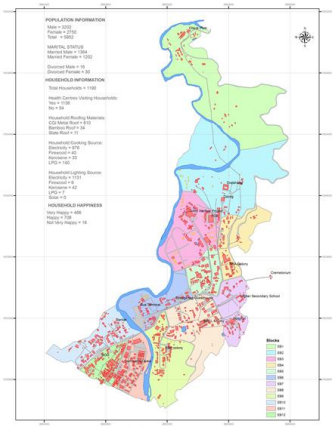
As mandated by United Nations Population Strategy, it is mandatory for every country in the world to carry out the population & Housing Census to know the population of the country and its amenities. Knowing the population statistics would have great impact on the country's economy, Welfare of the citizens, and eventually provide the basis for the policy makers and the development partners.

Hence in line with the United Nations Mandate, Bhutan has conducted her first ever population and housing census in 2005.

The office of the census Commissioner along with the senior policy makers made an important decision to include the application of Geo-Spatial Technology for this population project. Meaning that application of GIS (Geographical Information System) and GPS (Global Positioning System) to be included and **in fact made a real impact all through the process**.

For the **rural areas**, the rural settlement data collection was done using GPS. For the **urban areas**, data collection was done with GPS as well as the Trimble total stations.





The maps represent rural settlements and the building footprint of urban town of Bhutan.

The database was created and based on the structure clusters & density of rural and urban settlements foot prints, enumeration area were created using GIS and Geodatabase. All the statistical information were integrated with Geodatabase and prepared thematic/Statistical maps for dissemination as the census reports and census atlas maps

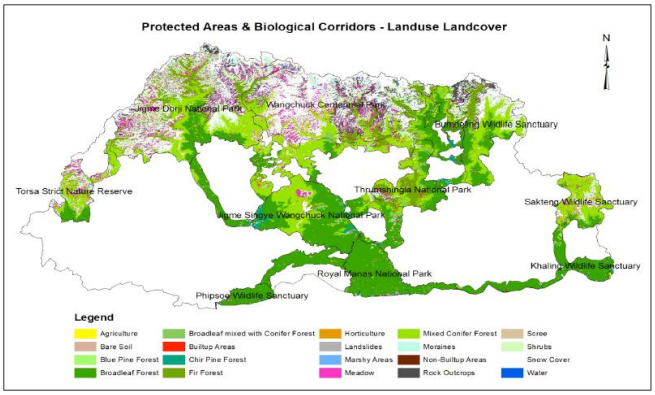
Conservation Planning of Bhutan and Geo-Informatics

In order to achieve sustainable development, Conservation Planning that balances the utilization, conservation and preservation of resources; and generates the fare share to the community and industry in terms of ecosystem services benefits and financial benefits are essential.

The protected area system represents all the major ecosystems of the country ranging from the tropical/sub-tropical grasslands and mixed deciduous forests in the southern foothills through temperate forests in the central mountains and valleys to alpine meadows and screes in the northern mountain. Presently, there are five national parks, four wildlife sanctuaries, one strict nature reserve and 12 biological corridors which cover more than 19,700 square kilometer, corresponding to more than 51% of the country's topographical area.

Geo-Informatics is applied for carrying out the following conservation planning and conservation activities in Bhutan. There are 19 activities which associate with Geo-Informatics for conservation planning in Bhutan - **1**. Resource and Biodiversity Inventory of Protected Areas and Biological Corridors, **2**. Park Zonation to Core Zone, Multi-use zone, Buffer zone, Wilderness zone and Research Zones in order to balance between the eco-centric management planning and egocentric management planning of the park, **3.** Human Wildlife Conflicts Management, **4.** Anti-Poaching Activities**, 5.** Alternative to Natural Resources to the Community, **6.** Ensuring Food and Raising Income for Community, **7.** Solid Waste Management, **8.** Sustainable Grazing and Livestock Management, **9.** Development of Conservation Infrastructure, Communication and Mobility, **10.** Ecotourism Development, **11.** Water Resource and Watershed Management, **12.** Climate Change and Adaptation, **13.** Conservation Education and Awareness Building, **14.** Integrated Conservation Development Plan, **15.** Landscape and Species Conservation, **16.** Forest Resource Management, **17.** Forest Fire Management, **18.** Research and Information Development, **19.** Area based Monitoring and Evaluation

Geo-Informatics is applied in order to map the resources and conservation financial requirement for each protected area of Bhutan. The following map describes the protected area system of Bhutan.

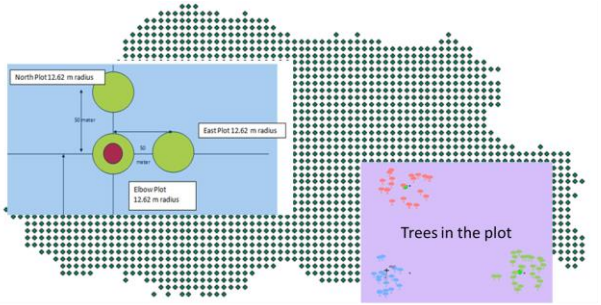


Forest Resources Management and Geo-Informatics

The total forest is 27052.81 km^2 which represents 70.46% of total land cover. Geographic Information Systems (GIS), GPS and Sampling Statistics is essential tools to design the sampling framework, sampling intensity and sample plot design for the National Forest Inventory and Forest Resources Potential Assessment of Bhutan in order to achieve the desired % Margin of Error. There are 2424 Cluster Plots at 4 KM interval throughout Bhutan to achieve 15% Margin of Error. The size of each cluster plot is 0.15 Ha.

GPS and data dictionary of GPS are applied in order to navigate to each cluster plot, its sub-plots and recording the location of individual tree and its attributes digitally (paperless) for data analyses in GIS and Statistics using R.

The following figure illustrates the NFI framework of sample plots.



Cluster of 3 circular Elbow Plot, East Plot and North on an L-shaped transect spaced at 50 meter apart. Each plot has a radius 12.62m (approximately 0.05 Ha). One 3.57m subplot allocated in middle elbow plot for regeneration data collection.

Total 2424 cluster plots (7272 plots). Each cluster plot has 0.15 Ha (0.05 * 3) are allocated at 4 km by 4 Km spacing throughout Bhutan.

Partially completed National Forest Inventory Reports important quantitative resource values in the following table related to forestry. One of the important data is National average and divisional (Dzongkhag) average value of mean volume of timber per hectare, number of trees per hectare and statistics of **reliability of information or statistical errors**. It is important information for forest management planning and to avoid over exploitation of the timber resources.

	Lower Limit Volume (cu-m)/Ha	Mean Volume (cu-m)/Ha	Upper Limit Volume (cu-m)/Ha	MoErr%	SE%	CV%
FRPA	159.85	**220.4**	281.04	27.49	16.48	135.9
Haa NFI	195.93	250.95	306.37	22.1	13.25	112.43
Tsirang NFI	31	250	470	87.67	52	324
Paro NFI	128	196	263	34	20	145
FRPA&NFI	179.25	226.84	274.43	20.98	12.7	193.5
	Lower Limit Trees /Ha	Mean Trees /Ha	Upper Limit Trees /Ha			
FRPA	157.73	181.67	205.6	13.18	7.9	65.15
Haa NFI	168.66	202	235.22	16.48	9.89	83.9
Tsirang NFI	190	237	283	19.68	11.67	72.92
Paro NFI						
FRPA&NFI	176.57	193.59	210.61	8.79	5.32	81.09

Geo-Informatics is an essential tool for creating Potential Forest Production Area (FPA) and Potential Forest Production Unit (FPU) for sustainable forest resource management at the National Scale.

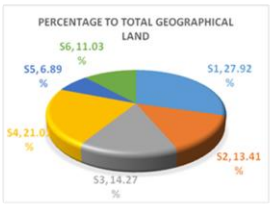
A total of 9 spatial criteria are derived in order to protect human habitats, infrastructure, aesthetics values, ecosystem function and hydrology. These include:

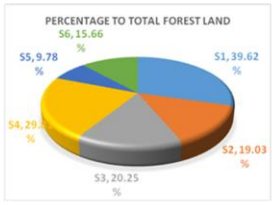
1. Only in forest lands below or equal an elevation of 4000m above mean sea level
2. Not within 200m either sides of roads (highways, feeder roads, farm roads, etc.)
3. Not within 30m from major drainages
4. Not within 1 km from rural settlements
5. Not within 1.5 km from towns
6. Not within RAMSAR wetland sites
7. Not within existing botanical, recreational parks and heritage forests
8. Not within existing Forest Management Units (FMUs)and Working Schemes (WS)
9. Not within existing Community Forests (CFs)

Further based on functionality of forest lands and objective of management, analysis was carried out in six different areas which resulted into six different scenarios. These six scenarios include;

1. Potential forest production area of the country (S1 for slope < to 45 ^{o} and S11 for slope < 35 ^{o})
2. Potential forest production area outside protected area (S2 for slope < to 45 ^{o} and S22 for slope < 35 ^{o})
3. Potential forest production area inside protected area (S3 for slope < to 45 ^{o} and S33 for slope < 35 ^{o})
4. Potential forest production area outside major watersheds (S4 for slope < to 45 ^{o} and S44 for slope < 35 ^{o})
5. Potential forest production area inside major watersheds (S5 for slope < to 45 ^{o} and S55 for slope < 35 ^{o})
6. Potential forest production area outside protected area networks and major watersheds (S6 for slope < to 45 ^{o} and S66 for slope < 35 ^{o})

Distribution of Forest Production Area which are less than 45Degree Slope with respect to total land area and total forest area.





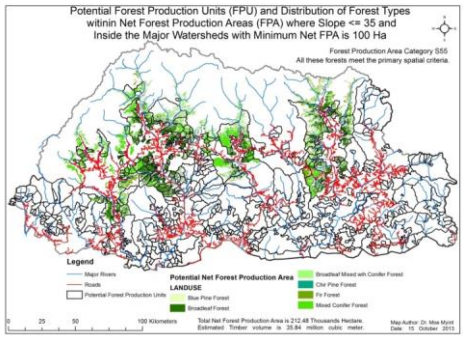
Distribution of Forest Production Area which are less than 35 Degree Slope with respect to total land area and total forest area.

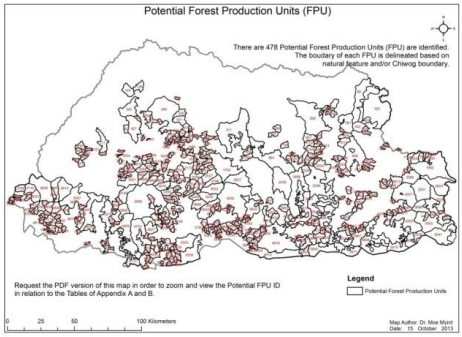
Based on slope less than or equal to 45^o, a total of 1071.83 thousand hectare of forest land was potential for forest management which is equal to 27.92% of country's geographical area and 39.62% to total forest land. Potential forest area feasible for sustainable management based on slope less than or equal to 35^o is 892.68 thousand hectare which is equal to 23.25% of country's geographical area and 33% to total forest land. A detail of potential area based on forest function and management objectives with slope $\leq 45^o$ and slope $\leq 35^o$ are illustrated in the pie charts above.

Based on the natural features, forest potential production area (FPA) was delineated into forest production units (FPU) for ease of field truthing and management. A total of 478 units (FPU) were delineated. Production units not only encompass net forest potential production area but also include other adjacent land use types. Area of production units ranges from minimum of 100 hectare to maximum of 52000 hectare. However, smaller units can be merged together to form bigger production units and vice-versa based on the suitability and objective of management.

Watershed and hydropower development of Bhutan and Geo-Informatics

Preservation of forest cover in major watersheds contributed sustainable water flow throughout the year for electrical power generation by using hydropower development. Geo-Informatics and hydrology stations data identified the six major watersheds of Bhutan electrical power production by using hydropower development. The forest covers in major watersheds contributed sustainable water flow for hydropower plants throughout the year.
The following maps illustrate the Forest Area in the major watersheds and throughout the Bhutan as potential production units which could be conserved for hydrology and ecosystem services or utilized for timber production.





By considering the environmental and social impact, Geo-Informatics, water resources engineering and economics identified the four existing hydropower generating plants of Bhutan. These plants have been producing hydropower energy from 3336.62 GWh in 2006 to 6811.27 GWh in 2012. Moreover, additional 12 hydropower plants are identified and planned to commission from 2013 to 2023. By combining the energy production capacity of existing and planned power plants, the energy production capacity will increase from 6811.27 GWh in 2012 to 19885.8 GWh in 2018 to 32183 GWh in 2020 to 45491.96 GWh in 2023. Bhutan exemplifies that hydropower plants contribute green energy of the country and good reasons to preserve the forest cover or to reforest the watersheds.

The Bhutan Sustainable Hydropower Development Policy (2008) explicitly states that power Generation Company or corporation shall provide minimum 1% royalty energy in cash for the purpose of catchment and watershed management through sustainable land use practices and nature conservation woks. The annual contribution from the hydropower sector for the conservation will increase $0.37 million in 2012 to $2.46 million $ in 2023 by implementing the Bhutan Sustainable Hydropower Development Policy (2008) for the green development. Moreover, hydrology service values of forests (264.61 thousands Ha) in the major watersheds worth 118.91 million USD in 2006/2007 to 1621.17 million USD in 2023/2024 based on the Economic analyses with GIS.

Summary Discussion

This paper highlights the application and role of Geo-Informatics in Bhutan for the National Development Planning, conservation of renewable resources and creating the National Income by conservation of forest and generating of green energy for the better quality of the life of Bhutanese.

This paper is not a research paper. However, this paper hope to convey the message to the mid-level and high-level authorities on how the Geo-Informatics technology could be applied for the National Development Planning for better quality of the life of the people especially in the developing world.

The modernized spheroid and datum; and standardized coordinate system for the National Geographic Framework is essential to streamline the modem spatial information system and to be compatible with readily available global and regional data sources. It is the foundation of advancement for application of Geo-Informatics for development planning.

The topographic sheets of the Nation should be scanned at very high resolution for geo-referencing of remotely sensed data, to use as the background thematic and topographic information for the analyses. Moreover, the digital elevation models and the digital terrain models should be created for the topographic and hydrological analyses at the national, watershed, landscape and local scales using scanned topographic sheets, digital photogrammetry, radar interferometry and LiDAR technologies.

The high quality land use, land cover, forests and resource information as the digital maps at minimum 10 meter to 30 meter resolution is essential for the National Development Planning. The preferred scale is 10 meter resolution. The data resolution which is greater than 30 meter should only be applied for monitoring purpose. It should be cautioned that low resolution satellite data are freely available and the data produced from the low resolution satellite images should only be applied with great cautions especially for the national spatial planning purpose at the national and local level because most low resolution products are suitable only for monitoring and modeling purposes.

The population and housing census information which is geo-referenced to the individual rural household and urban footprint is essential and important for the mobilization of resources and planning the accessibility of energy and other utility structures; and industries for the better quality of life of the people at the landscapes of the Nation.

The cadastral survey is important especially for the land tenure and land ownership at the parcel level in order to create the detail Geodatabase on actual land holding size of people. Integration of very high resolution satellite images, drone images and field survey could create or update cadastral database relatively more cost effectively and easier than before.

All the metrological stations and hydrological stations should be geo-referenced and disseminate the daily weather and hydrology data as the digital spatial database format to the users who applied the biophysical information for development planning.

Conservation is essential to maintain the ecological integrity of the Nation. However, it is important to recognize the balance between preservation, conservation and utilization of natural resources for development planning. Too little conservation could be catastrophic to the ecological integrity of the country while too much conservation could be luxury especially for the developing country. This paper highlights the Geo-Informatics as the balancing tool to estimate and indicate where and how much to conserver and to utilize for the benefits of people, future generation and ecosystem integrity without exploitation or depriving; and providing fair share of benefits to the rural community, industry community, wildlife and ecosystem.

Multi-resource inventory and assessment such as National Forest Inventory, Forest Resources Potential Assessment and biodiversity inventory are essential and could be successfully integrated to Geo-Informatics for development planning. The compensation of los of ecosystem services, loss of forest cover, loss of biodiversity and payments for environmental services could be estimated as the resource quantity and monetary value based on the multi-resource inventory and assessment. This paper highlights the distribution of resources quantity in different categories of land utilization such as major watersheds, protected areas and outside of these areas for decision making by the policy makers of the country.

Daily hydrology, daily meteorology, geomorphology, geology, soil, topography, stream and river network, land use, infrastructure, forest, vegetation, biodiversity, population and socio-economics of major watersheds are essential for the watershed and landscape level development planning, hydropower planning for the Nation. Major watershed Geodatabases should be created throughout the development planning process which could create enormous national income opportunity through conserving the forest of watershed for producing the green energy such as hydropower for domestic and power export. This paper provides an example for valuing the environmental resources using Geodatabase.

The paper would like to caution - due to the complexities of spatial information, inappropriate choice of low resolution data for high resolution applications with fast computers, these days one can make bigger and better mistakes faster than ever for producing the low data quality spatial information such as land use and land cover at a rapid race. The data quality check is important before applying the data for the national level planning. The role of estimation and the role of reliability of estimates in term of statistical errors such as Percent Margin of Error or

Percent Standard Errors are important to evaluate the estimation quality and data analyses. Based on Burrough (2006) - An old computer Adage of "*garbage in garbage out!"* could apply truly in Geo-Informatics use.

Conclusion

Capacity building of Geo-Informatics and Geo-Statistics to the science professionals, social scientists, planners, economists and engineers are important in order to make spatially intelligent decision supporting and decision making for their professional domains and national development planning.

Policies, laws and rules which favors the "Compensation of loss of forest cover and timber volume, biodiversity, hydrological services and ecosystem services should be paid as the fair share by the development project to the rural community, industrial community or regulating departments which did the restoration work" are very important for sustainable management of natural resources and National development planning from the point of views of conservation planning, sustainable financing for conservation and national development planning.

References

Burrough, P.A, McDonnell, R.A (1998), Principles of Geographic Information Systems, 2nd edition, Oxford University Press

Myint, M (2013), Bhutan Project Finance for Permanence - Financial Proposal for Protected Area System of Bhutan: Sustainable Financing Options for Conservation in Bhutan, WWF Bhutan

Myint, M (2013), Bhutan Project Finance for Permanence - Conservation Planning for Protected Area System of Bhutan: Sustainable Financing Options for Conservation in Bhutan, WWF Bhutan

Myint M, Tshering K, Rai A, Katwal S, Penjor U, Deki K (2013), Forest Resources Potential Assessment (2013) Bhutan, Forest Resources Management Division (FRMD), Bhutan

National Soil Service Center & PPD (2011), Technical Report on Bhutan Land Cover Assessment 2010, Ministry of Agriculture, Bhutan

Office of Census Commissioner (2006), Results of Population & Housing Census of Bhutan (2005)