CHAPTER - VI

OVERVIEWS AND CONCLUSIONS

Traditional agriculture is an important activity in the study region. About 91% population depends on agriculture, livestock rearing and gathering the minor forest products for livelihood. Physiographic components i.e. geology, topography, soil, availability of nutrients, amount of rainfall, etc. play a fundamental role in agriculture and closely associated with land productivity. However, lands of the study region are facing problems like heavy run-off, heavy soil erosion, loss of fertile soil, low crop yield, shortage of water, etc. Subsistence economy, poverty, illiteracy, subjugation, etc. are major problems of farmers in the study region. The low productivity and unemployment resulted in seasonal out migration in search of employment. Therefore, present study has been focused on LSA and planning for sustainable agriculture. GIS based MCDM approach using IRS P6 LISS-IV dataset has been used to analyse LS for agriculture and plantation. Water resource is influencing the cropping pattern, productivity, etc. Therefore, climatological approach has been adopted for crop selection.

SMAI has been calculated and plotted (SMAC) to understand temporal variation in SM availability in the region. LS for agriculture and plantation and dynamics of water resource in the region have been taken into consideration to suggest crops i.e. Rice, Wheat, Nagali, Varai and Khurasani and plants i.e. Cashew and Mango. Thus, the study reached to final overviews and conclusions as below.

6.1 Overviews

A. General

1. Lands in the hilly zone are facing problems like heavy run-off, heavy soil erosion, loss of fertile soil, ground water depletion, low crop yield, shortage of water, etc.

2. Poverty, food insecurity, malnutrition, subsistence economy, illiteracy, etc. are major problems of farmers in the study region.

3. LSA is a method of evaluating the appropriate lands for specific uses i.e. agriculture, plantation, settlement, urbanization, environmental planning, waste management, water resource management, tourism, etc.
4. The techniques i.e. analytical hierarchy process, weighted linear combination, ordered weighted averaging, concordance analysis, etc. are widely used for LSA with GIS techniques to detect the potential lands for agriculture.

5. GIS and RS are more reliable and efficient techniques of LSA performed based on different physical and socio-economic parameters of the region.

6. MCDM with GIS techniques provides more flexible and precise decisions to evaluate the effectiveness of criterion.

7. MCE techniques are better for multiple criterions involved in the decision making process with different degree of influences.

8. MCE techniques are useful for integration of information related to different land elements in decision making process for SLM.

9. AHP is mathematical technique widely used for weight determination through PCM and complex decision making process.

10. PCM is helpful to assign different levels of criterion for decision making.

11. Moderate resolution satellite data i.e. TM (30m), ETM, ETM+ (28.5m), NOAA AVHRR, Terra ASTER, etc. widely used for detection of suitable areas for crops.

12. Fine resolution satellite data i.e. QuickBird, IKONOS, RapidEye and LISS-IV, etc. are better for result oriented LSA than the low and moderate resolution data sets, especially in hilly zone.

13. Conventional data i.e. soil map, field work, laboratory data, government records, etc. have been used for LSA in different field.

14. Criterion like slope, LULC, soil depth, soil texture, soil moisture, soil nutrients, soil erosion, etc. used for analysis of land qualities and suitability for agriculture.

B. Physiographic set up

1. Study area is situated in mountain zone, Sahyadri and has rugged and undulating topography.

2. Three spurs running from West to East i.e. Kalsubai Range at North, Baleshwar Range at middle and Harishchandra Garh at South.

3. Mature type of topography with hill slopes, valleys and sub-rounded weathering products are evidences of Pahoehoe flows.
4. Altitude varies from 700m in Eastern part to 1646m Western border in Pravara basin and 620m to 1424m in Mula basin at Western border.

5. Gentle slopes occupy about 5% of TGA, moderate slopes 11%, stiff slopes 14%, steep slopes 20%, very steep 20%, extra steep 17% and precipitous slopes 13%.

6. Gentle slopes are distributed in narrow track along Mula and Pravara and moderate sloping ground at foothill zones.

7. Stiff slopes are covered by dense forest and farmers of this region have terraced some of the patches for agriculture.

8. Steep sloping grounds are prone to heavy soil erosion with coarse and thin soils. Therefore, steep to precipitous sloping areas are not suitable for agriculture.

9. Topographically, most of the areas are of the study region is adverse and permanently unsuitable for agriculture.

10. Ratangad - Baleshwar ridge runs West-East direction and water divide between Pravara and Mula basin.

11. Pravara and Mula are originate on Eastern slopes of the Sahayadri i.e. Ratangad and Harishchandra Garh, respectively and flowing toward East about 21 miles.

C. Soils

1. Loam (65%) and clay loam (35%) soils are observed in the study region.

2. These soils are classified into five classes based on depth as: thin (4%), shallow (21%), marginal deep soil (17%), moderate deep soil (42%) and deep soil (23%).

3. Deep and moderate deep soils have higher water retention capacities, enough moisture, normal pH, moderate nutrients and potential lands for agriculture.

4. Deep soils are distributed on gentle slopes and foothills whereas very thin and shallow soils distributed on steep to precipitous slopes.

5. Average value of pH is normal (6.5) and highly suitable for agriculture and plantation.

6. EC is less than one and highly suitable for agriculture and plantation.

7. Average value of SOC is 0.8%. It is more in Mula (0.8 to 1%) than Pravara basin (0.4 to 0.6%).
8. Available N in deep soils is highly suitable, in moderate deep soil is moderately suitable and in thin and shallow soil is marginally suitable.

9. Average value of P is estimated about 17.39 kg. It is marginally suitable for agriculture and external inputs required for optimum production.

10. Average of potassium (K) is (395.6 kg/ha) with maximum (527.8 kg/ha) in Mula basin and minimum (215 kg/ha) in Pravara basin.

11. Average MWHC of soil in the study area is about 33.63% (thin soil), 106.25 mm (shallow soil), 199.61 mm (marginal deep soil), 280.42 mm (moderate deep soil) and 422.02 mm (deep soil).

12. About 42.1% of the soils in reviewed area show more than 400 mm MWHC and more secure for crops in Kharif season.

13. About 17% lands occupy thin and shallow soils have less than 100 mm MWHC, insufficient for crop.

14. About 64% reviewed lands are slightly eroded, 14% lands moderately eroded and 17% land intensively eroded.

15. Slightly eroded lands are highly suitable for agriculture in this region, some of the patches of moderately eroded lands are terraced for cultivation. However, highly eroded lands are not suitable for agriculture.

16. Steep slopes, coarse soils, heavy soil erosion, high discharge, etc. are identified major problems in the region.

D. Climatological condition

1. The rainfall varies from 4935 mm at Western border (Ghatghar) to 1478 mm at Eastern (Dhamanvan) of the region.

2. Rainfed Kharif crops in the region have assured rainfall and Rabbi crops require irrigation.

3. Rain water resource is major source of water for agriculture in Kharif season.

4. The assurance of rainy season is more than amount of rainfall shows in weekly rainfall analysis. Further, annual rainfall is more assured than seasonal distribution.

5. Average weekly minimum and maximum temperature is 19.4°C and 30.3°C, respectively.

6. Estimated annual PE is about 1360 mm with distribution of 342 mm in Monsoon, 330 mm in Rabbi and 688 mm in Summer season.

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7. Average humidity is 69.2% with maximum 84.4% and minimum 54.0%. It is highly suitable for Mango and moderately suitable for Cashew.

8. Average monthly sunshine hours are 6.9 hrs./day with minimum hours in month of July (2.5 hrs./day) and maximum in February (9.5 hrs./day). Sunlight is enough for plants growth.

9. Assured cropping season is from 24th to 35th week for Kharip crops i.e. Rice, Nagali, Varai and Khurasani.

E. Population

1. The total population in region is 54775 distributed with distribution of male (50.28%) and female 49.71%).

2. The villages situated in hilly zone have less density than located in the areas of comparatively gentle slopes with deep soils.

3. Population of Scheduled Tribes i.e. Mahadev Koli, Thakar, etc is about 91% of total population and dependent on agriculture.

4. About 91% of total human power engaged in agriculture as cultivators (71%) and landless laborers (20%).

5. The working population (55%) is categorized as main workers (87%) i.e. male (52%) and female (48%) and marginal workers (13%) i.e. male (39%) and female (61%) workers.

6. Human power is observed more in Pravara basin on gentle sloping lands with deep soils than Mula basin.

7. Dense population of cultivators (113 persons/ 100 NSA) observed in 48% villages situated the areas of gentle slopes, fertile soils, good water resources, etc.

8. Sparse population of cultivators is observed in the areas of steep slopes, shallow soils, water scarcity, etc. in mountainous zone.

9. Female main agricultural laborers (65%) and marginal agricultural laborers (69%) in the region are more than the male.

10. The working population of the study area is increased by 5.38% in the last decade.

11. About 65% of total population i.e. male (59%) and female (41%) are literate with 7% growth in the last decade.
12. Agriculture is a major source of income to population in the region especially for socially and economically suppressed section of the society i.e. scheduled tribe and women.

13. Adverse topography, thin and dry soils, water scarcity, inaccessibility, etc. have influence on distribution of population.

14. The workers in the study region are migrating in search of employment after *Kharif* season.

F. **Land use**

1. The area under agriculture has been estimated about 51% of TGA dominantly distributed in the narrow track along Mula and Pravara.

2. TGA is categorized in NSA (42%), fallow land (9%), area not available for cultivation (8%) and forest (40%).

3. Lands with steep slopes, thin soil, less soil moisture, less water retention capacities as well as more erosion show less NSA whereas more NSA observed on gentle slopes with deep soils near to Mula and Pravara.

4. Most of the agricultural areas of villages located around Bhandardara dam have submerged under water body and classified in the area not available for agriculture.

5. Dense forests are observed in Western region with deep soils at foot hills.

G. **Cropping pattern**

1. Gross cropped area in the study region is about 19027 ha including 19008 ha single cropped and 19.29 ha doubled cropped.

2. Double crops are observed on deep soils with irrigation.

3. The major cereals in the region are rainfed Rice (37% to NSA), *Nagali* (4.36% to NSA), *Varai* (3.37% to NSA) and *Bajara* (0.2% to NSA) in *Kharif* season.

4. Rice, *Nagali* and *Varai* are observed in high rainfall at West zone whereas *Bajara* in Eastern zone with comparatively less rainfall.

5. The pulses like *Hoolga* (0.79%), *Mug* (0.05%) and *Tur* (0.03%) cover less than 1% of NSA in *Kharif* season in Eastern part with less rainfall.

6. The oil seeds cover about 3% of NSA including *Khurasani* (2.65%) and *Groundnut* (0.63%).
7. Grass lands, wild grasses occupy about 52% of NSA in the region and give minor financial supports to the farmers.

8. The average productivity of Rice in the study region (1.3 t/ha) is less compared to Maharashtra state (2.01 t/ha).

9. Variations in slope are negatively (-0.73) and soil depth is positively associated with productivity of Rice (0.80).

10. Short duration Rice varieties like Poonam and Daptari-100 are observed on terraced slope, moderate soils with medium MWHC whereas long duration varieties Indrayani and Sonam on gentle slopes with deep soils at bottom of the valleys.

11. The productivity of Nagali (11 QI/ha), Varai (9 QI/ha) and Khurasani are varies with changes in slopes.

12. Slope is positively associated with productivity of Nagali, Varai and Khurasani. Therefore, these crops grow on sloping lands.

13. About 11% villages are observed in the area under Bajara (0.2% of NSA).

14. The productivity of all crops in the region is observed less compared to developed areas.

H. Land suitability for agriculture and plantation

1. Remotely sensed IRS P6 LISS-IV satellite data sets are useful for detection of suitable lands for agriculture and plantation.

2. GIS based multi-criteria evaluation technique is useful for LSA in hilly zone.

3. The pairwise comparison matrix is useful for decision makers to assign different levels of importance to different factors involved in LS.

4. Weights were calculated to criterion using judgment in pairwise comparison matrix and score has been assigned to sub-criterion.

5. The higher score indicates maximum influence of sub-criterion whereas lower score shows least suitability for agriculture and plantation.

6. Twelve criterion i.e. slope, LULC, soil depth, MWHC, moisture, texture, erosion, pH, EC, SOC, N, P and K were selected for LSA for agriculture in the present study.

7. Correlation analyses are helpful for robust judgment of ranking the criterion for LSA.
8. Ranks of criterion were determined based on expert opinion, literature survey and correlation analyses.
9. Slope, LULC, soil depth and soil texture show higher influence on agriculture in the region.
10. SM, MWHC and erosion vary according to slopes and soil depth and have medium influence on agricultural production. Therefore, they are rated middle position.
11. Slopes and soil qualities i.e. soil depth, MWHC and nutrients show significant relationship with productivity of major crops like Rice, Varai, Nagali and Khurasani.
12. OC, pH, N, P, and K show that comparatively less significance with crop yield in the study area. Therefore, they are rated last.
13. Steep to precipitous slope, erosion degrees along with thin and shallow soil depth of the study area were most effective factors resulting permanently not suitable for agriculture and plantation.
14. Soil nutrients i.e. EC and pH are highly suitable for agriculture.
15. The nutrients like N, P and K are available at marginal to moderate level required external inputs for agriculture and horticulture.
16. Highly suitable lands have no significant limitations for existing cropping pattern i.e. Rice with possibilities of intensive agriculture, if irrigation provided.
17. Moderately suitable lands are also suitable for agriculture but proper farm management required.
18. Marginally suitable lands show medium suitability for crops like Nagali, Varai and Khurasani with requirements of terracing, additional inputs like fertilizers, protection from intensive run off and erosion, etc.
19. Areas of steep slopes, very thin soils, open rocks, dense reserve and protected forests, settlements, roads, etc. are not suitable for agriculture.
20. The final output raster maps have generated using weighted overlay techniques and allotted score were averagely converted into four classes i.e. 9, 7, 4 and 1.
21. Finally, these classes have reclassified into four suitability levels i.e. highly suitable, moderately suitable, marginally suitable, and not suitable.
22. About 17% of reviewed land is highly suitable, 29% is moderately suitable, 16% is marginally suitable and 38% is not suitable for agriculture.

23. About 5% of reviewed land is highly suitable, 23% moderately suitable, 14% marginally suitable and 58% not suitable for plantation.

24. The land suitability classes i.e. ‘highly suitable’ and ‘not suitable’ in suitability map are precisely estimated than the classes ‘moderately suitable’ and ‘marginally suitable’ both in producer’s and user’s point of view.

25. The moderately and marginally suitable lands have estimated less than producer’s (84% and 89%) and user’s (90% and 86%) accuracy than the producer’s accuracy (97.36% and 97.67%) and user’s accuracy (90.24% and 95.45%) of highly suitable lands and not suitable lands

I. Crop selection

1. Water balance technique suggested by Thornthwait and Mather (1956) is useful for analysis of water resources for crop selection.

2. AE has been calculated for ten raingauge stations in the study area according to soil types i.e. 25mm, 100mm, 200mm, 300mm and 400mm MWHC using SM retention table given by Thornthwaite and Mather (1956).

3. Water balance has been calculated to prepare SMAC based on SMAI calculated using weekly AE and PE.

4. AE has significant positive relationship (0.99) with MWHC and WD shows negative relationship (-0.96).

5. Humid conditions are observed in Kharif season and immediately dry out after rainy season. Therefore, SM conditions are suitable and secure for agriculture on all soil types in only Kharif season.

6. Length of available wet and humid SM conditions is about 174 days in deep soils, 166 days in moderate deep soils, 156 days marginally deep soils, 140 days in shallow soils and 110 days in thin soils.

7. Crops and their varieties have been selected based on duration of life cycle of crops, SMAC, rainfall assurance calendar, rainy days assurance calendar, physiographic feasibilities, etc.

8. The number of humid and wet weeks increases with MWHC in soils. Therefore, water is stored for long duration in deep (174 days) and marginal
deep soils (166 days) in *Kharif* and *Rabbi* seasons. Therefore, these soils are more suitable and suggested for long duration Rice varieties.

9. **Rice: varieties group - A** i.e. Basmati, Indrayani, Sonam, Bhogawati, Ratnagiri-2, Kajat-2, Masuri and Darni have suggested for deep soils.  

10. **Rice: varieties group - B** i.e. Prabhavati, Sugandha, Daptari-09, Phule Samrudhi, Ratna and Parag have suggested for moderate deep soils.  

11. **Rice: varieties group - C** i.e. Poonam, Daptari-100, Karjat-184, Ratnagiri-1, Ratnagiri-4 and Ratnagiri-711 suggested for marginal deep soils.  

12. Length of available humid and wet SM conditions is more than life period of suggested Rice varieties.  

13. Shallow soils dry outs immediately after the rainy season and its water retention capacities also less. Therefore, this soil is suggested for Nagali, Varai and Khurasani.  

14. Life period of Wheat is 120 to 130 days and length of available wet condition of soils (deep and moderately deep) is about 110 days after rainy season. Therefore, these soils are suggested for Wheat in *Rabbi* season. However, irrigation required after January.  

15. Suitable lands for suggested crops are selected based on geophysical feasibilities and crop calendar.  

16. About 46% TGA is suggested for Rice categorised in three groups of varieties i.e. Group - A (17%) for deep soils with gentle to moderate slope, Group - B (14%) for stiff slopes and Group - C (15%) for steep slopes in *Kharif* season.  

17. About 15% of TGA with marginal suitability suggested for Nagali, Varai and Khurasani in *Kharif* season.  

18. About 17% of reviewed lands are highly suitable and 13% moderately suitable for Wheat in *Rabbi* season.  

19. About 42% of TGA is suitable for Mango and Cashew plantation with three classes i.e. highly suitable (5%), moderately suitable (23%) and marginally suitable (14%).
6.2 Applicability of the study

The methods like correlation technique, AHP based MCDM methods and water balance analyses are useful for decision of suitable lands for different crops and plants in hilly zones. Therefore, the outcomes would be helpful to plan the programmes of agriculture and plantation to improve the income to the tribal people living in the region. The present study also helpful for planning of conserving the natural resources i.e. soil, water, forest, wild animal, etc. and increasing efficiency of the national action plan against land degradation. LSA is important for enhancing land productivity for different crops and helpful to minimize the migration from tribal zones. Therefore, the present study is useful to farmers, NGOs and projects undertaken by government agencies especially for hilly zones.

Fine resolution RS data, experts’ opinions and statistical techniques i.e. correlation analyses have been used to achieve robust results. This is quite innovative technique of ranking the criterion. Therefore, outcomes, methods and techniques used in this study are useful to students, researchers, planners, etc. for LSA for different land use.

6.3 Limitations of the study

The researcher is aware about following limitations of the present study.

1) Data about temperature, PE, wind speed, humidity and sunshine hours recorded at nearest weather station located in Pravara basin at Induri has been used for climatologic analysis. The results based on data recorded within the study area may enhance and more precise than used data.

2) Information about land use and cropping pattern procured from government records vary from estimated land use using satellite data.

3) Thematic maps prepared using IWD interpolation techniques are generalized with less accuracy than results of satellite data. Overlay analysis of using these thematic maps show less precision for LS classes i.e. moderately and marginally suitable lands.

4) Experts’ opinions used this analysis show similar opinions to their research instead of requirements of present study and the regions.
5) Daily water balance analysis is more suitable to obtain precise estimations. This is more expensive and time consuming job. Therefore, in the present study weekly water balance has been calculated.

### 6.4 Conclusion

GIS based MCDM approach using IRS P6 LISS-IV dataset has been used to analyse LS for agriculture in hilly zone. The experts’ opinions and statistical correlation technique have been used to decide the ranks of influencing criteria and pairwise comparison matrix in Expert Choice Software used to determine the weights. The scores for sub-parameters showing internal variations within the criterions have also been assigned based on field work and reported norms in published literature. Water balance analysis has been used to understand water resource availability. The combinations of spatial and temporal analysis have been used for the preparation of planning strategy. The crops like i.e. Rice, Wheat, *Nagali, Varai and Khurasani* and plants like Cashew and Mango are suggested based crop calendar and LSA. Suggested crops would help to increase profit to the farmers with environmental friendly agriculture.

Thus, the major objectives of the study i.e. to study physiographic and socio-economic environment, analyses the LS for agriculture and plantation based on geographic feasibility and suggest suitable crops and plantation for selected study region are achieved, successfully. The results of the study are useful for farmers in the study region to improve their income and profitability as well as to students, researchers and planners in this field.

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