



Geomatics based concurrent evaluation of plantation drive in Jhansi District

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Abstract

Modern tools viz., GIS, GPS and satellite remote sensing play vital role in the assessment of plantation as well as estimation and up scaling of forage production. 'Special Plantation Drive' (SPD) in Bundelkhand region was initiated by the Government of Uttar Pradesh. About 28.70 thousand ha land was targeted to be planted with 28.50 million trees in Jhansi Division during July to September 2008. The target for Jhansi district was fixed about 9000 ha land with approximately 10 million trees plants. The overall performance of SPD in Jhansi district was found in good condition (SCM 30.02 out of 50). It was found good at 51.79% plantation sites, average at 20.54% sites and poor at 2.68% sites. Proper basin size and pits was found good at 14.29% sites whereas it was average at 34.82% and poor at 29.46% plantation sites of the district. Selection of tree species according to land resource unit was found an important indicator of the assessment of plantation work. It was recorded good at 54.46% sites and average at 45.54% sites in the district. The plant vigour and health was observed as good in 37.5% sites and average in 60.71% sites. Finally the percent survival of plants was recorded as good in 12.5% sites, average in 82.14% sites and poor in only 5.36% sites. Forage yield from plantation sites were estimated as 1.13 tDM/ha. It was found maximum (2.06 tDM/ha) on bunds reseeded with suitable grass and legumes species where as it was lowest (1.07 tDM/ha) in the rest part of the sites.

Key Words : Evaluation, GIS, GPS, Jhansi district, Tree plantation

Introduction

Economically and environmentally sustainable model of development for Bundelkhand region is needed not only to provide the livelihood to resource poor farmers but also to accelerate the agrarian economy (Singh *et al.* 2007). Natural tree covers are non-arable terrestrial

ecosystems and play vital role in the rural economy and environmental conservation (Pathak *et al.* 2005). It provides food, fodder and fuel and enriches the environment through soil and moisture conservation and carbon pool *etc.* In this direction 'Special Plantation Drive' in Bundelkhand Region was initiated by the Government of Uttar Pradesh. The target for Jhansi district was fixed to plant approximately 10 million trees on about 9000 ha land.

The monitoring of plantation programme through traditional method is time - consuming, costly, person-specific and difficult to cross verification. On the other hand, monitoring based on the modern tools and techniques viz., satellite remote sensing, GIS (Geographic Information System) and GPS (Global Positioning System) has several advantages. Timely, accurate, cost effective and date specific or periodic information (both spatial and non spatial) along-with geo-database and thematic maps on land cover or object /theme specific information can be generated with scientific explanations (Singh *et al.*, 2009). These modern tools are being widely used by many research organizations at national and international level.

Materials and Methods

The Study Area

The study area, *i.e.*, Jhansi district, is situated between 25° 30' N to 25° 57' N latitudes and 78° 40' E to 79° 25' E longitudes covering an area of 50299.53 ha. Administratively, it is divided into five tehsils and eight blocks (Fig. 1). There are 840 villages, out of which 759 are inhabited. Geographically it is located on *Bundelkhand* plateau. The relief of the district varies from 150m to 450m above msl. The northern tract of the district exhibits a plain like appearance dotted with isolated low rocky hills whereas the landscape of the southern part is undulating with bare rocky hills. Among the two main dissected ridges of the district, one starting near Baruasagar runs northeast through Jhansi and Moth tehsil; and the other one from extreme south of Mauranipur to the north. The landform

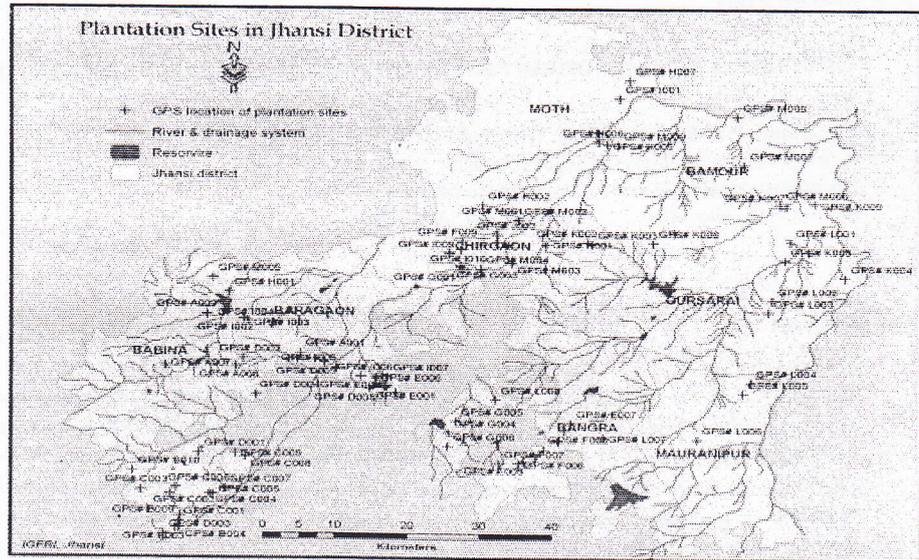


Fig. 1: Location of Plantation sites in Jhansi district

along the Betwa river is characterized by broken relief and many ravines have come up near the confluence of the Betwa and the Dhasan rivers (Singh *et al.* 2001). The rainfall pattern of the year 2008 is presented in figure 2. Removal of tree cover, free and excessive range grazing, unscientific land use and erratic nature of rainfall are the major factors causing environmental degradation. The past study (Singh *et al.* 1997), conducted at IGFRJ Jhansi, also reveals that the moderate to heavily degraded stages of vegetation vary in composition, density and distribution.

Methodology

1. GPS data recording and GIS integration: High accuracy GPS (Garmin GPS MAP-276 and 3006C) was used to collect the coordinates of plantation sites. IRS-P6-L3 data (dated, October, 2008) was used to characterize the plantation sites. ArcGIS ArcInfo workstation was used to display and analysis of spatial information and coordinates. Stratified random cluster sample technique revealed that most of the sites covered were from degraded and barren forest lands followed by common property lands of villages, urban and other lands including road sides (Fig. 1). Approximately 60% of the target (5400 ha area and 5.8 million plants) fall under the control of forest department situated in remote area having moderate to highly undulating terrain.

2. Score card method (SCM): Quantitative and qualitative assessment of plantation drive was done using Score Card Method (SCM). For this purpose, weightage based

score range was assigned viz. basin size (1-5), soil-water conservation technique (1-5), protection from animals (1-5), life saving irrigation (1-5), land resource unit and species selection (1-5), people's affinity towards SPD (1-5), plant vigor (1-5) and percent survival of plants (1-15) (Table 1). Indicators of all the observed sites were individually grouped into poor, average and good condition class on the basis of scores obtained (Table 2). The condition class of each observed plantation site was determined on the basis of total score obtained by a site viz., poor condition class (up to 15 mark), average (15-25), good (25-35) and very good (>35).

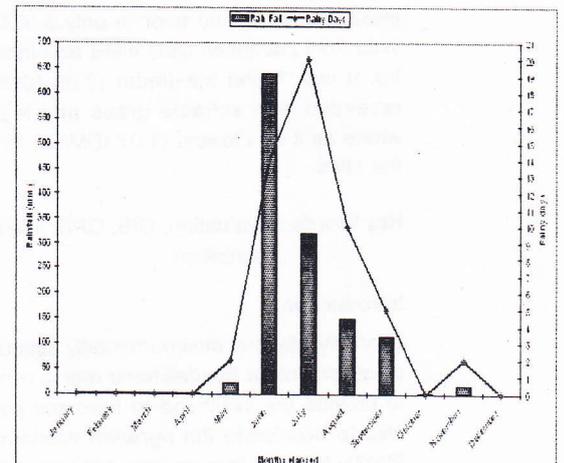


Fig. 2: Mean monthly rainfall and rainy days in year 2008 in Jhansi district

Table 1: Assessment of tree plantation using Score Card Method :

S.No.	Indicator	Score Range
1	Basin size (BS)	1 - 5
2	Soil-water conservation technique (SWCT)	1 - 5
3	Protection from animals (PFA)	1 - 5
4	Life saving irrigation (LSI)	1 - 5
5	Land Resource Unit and Species selection (LRU&SS)	1 - 5
6	People's affinity towards SPD (PA-SPD)	1 - 5
7	Plant vigour (PV)	1 - 5
8	Plants Survival (PS)	1 - 15

Total Maximum score = 50; Total Minimum score = 8

Table 2: Class conditions based on overall score:

Overall score	Condition class
< 15	Poor
15 - 25	Average
25 - 35	Good
> 35	Very good

3. Estimation of forage yield: Total 15 sites situated in different blocks on forest lands were selected for the study of forage yield. Samples were collected from bunds and fields.

4. Field observation and personal interview : Field observations provide an opportunity to interact with the stakeholders viz. primary beneficiaries, field functionaries and others who were directly or indirectly associated with this programme. In order to evaluate the work, frequent interaction and discussion were carried out with Forest Range Officers for plantations under Forest Department, Block Development Officers (BDO) and Gram Pradhans of village Panchayat as well as daily paid workers and villagers. After collecting the essential information, selected sites under plantation programme were assessed.

Results and Discussion

The field study was conducted during 11th July to 27th December 2008. Major agencies involved in the plantation drive were Forest Department, NREGS, Electricity Board, Social Forestry, Nagar Nigam Jhansi, Nagar Panchayats, Department of Horticulture, Irrigation Department, PWD, BDO and Gram Panchayat etc. The findings of the monitoring and concurrent evaluation of 112 selected sites and general field observation of about 26 sites under SPD Programme in Jhansi district is precisely summarized under the following heads:

1. Assessment of plantation

The best scientific way to evaluate the SPD in Jhansi district is to assess the important indicators related to the planting methods, protection and people response etc. Based on the techniques adopted in the assessment of tree plantation it was found that about 25% sites were in very good condition, 52% were in good condition (Table 4).

Table 3: Individual indicator assessment:

Indicator	Score	Condition class
Basin size (BS)	< 2	Poor
	2 - 3	Average
	> 3	Good
Soil-water conservation technique (SWCT)	< 2	Poor
	2 - 3	Average
	> 3	Good
Protection from animals (PFA)	< 2	Poor
	2 - 3	Average
	> 3	Good
Life saving irrigation (LSI)	< 2	Poor
	2 - 3	Average
	> 3	Good
Land Resource Unit and Species selection (LRU&SS)	< 2	Poor
	2 - 3	Average
	> 3	Good
People's affinity towards SPD (PA-SPD)	< 2	Poor
	2 - 3	Average
	> 3	Good
Plant vigor (PV)	< 2	Poor
	2 - 3	Average
	> 3	Good
Plants Survival (PS)	< 5	Poor
	5 - 10	Average
	> 10	Good

A. Basin size of tree plants (BS): Basin size plays an important role in the initial establishment and survival of the tree plantation. The study revealed that proper basin size was maintained for 14.92% tree plants and average basin size for 34.82% plants whereas it was below average for 29.46% plants (Table 5). The quantitative study based on SCM index, was found to be average (2.35) in the district. But at some sites of forest department, horticulture department, social forestry, and at some farmer's land especially at Palida, Ghisoli, Baroda, and Prithvipura in Babina block, Opara, Fatehpur and Sultanpura in Chirgaon block, Magarpur in Mauranipur block was found in very good condition (Figure 3). The SCM index was found between 3 and 5 (good) in Ghateshwar, Paresha, and Panari in Moth block.

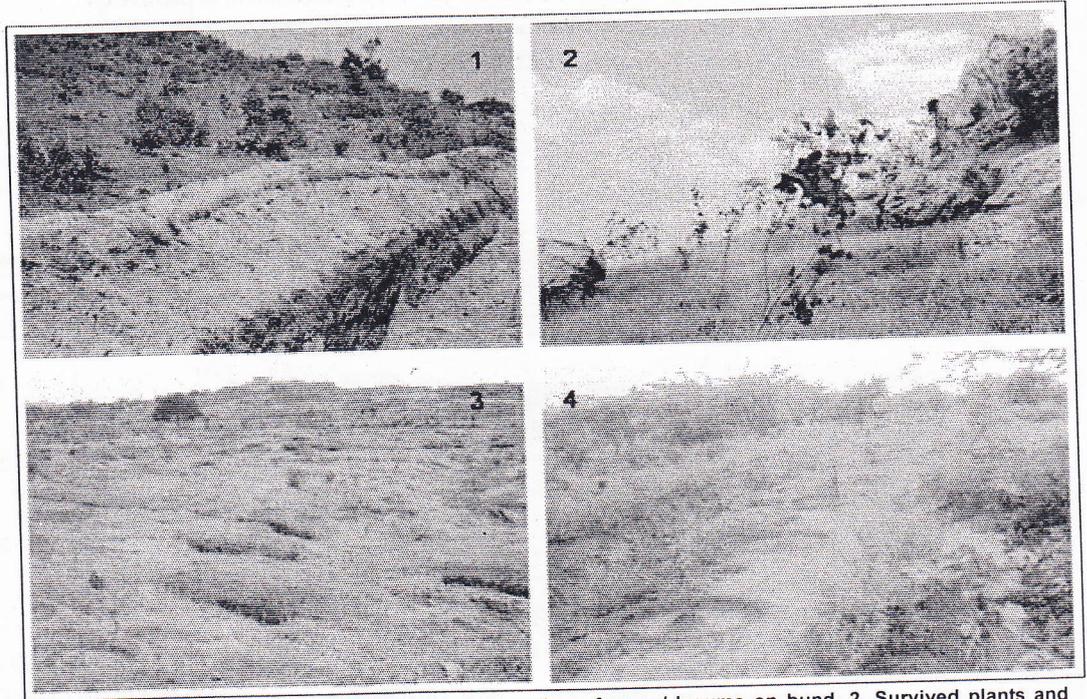


Fig. 3: Plantation sites - 1. Trenching and reseeded of grass/ legume on bund. 2. Survived plants and regeneration of natural grasses on hill slopes. 3. Soil water conservation technique adopted in the field. 4. Good size of basin and plants survival.

B. Soil and water conservation techniques (SWCT): Land treatment especially in undulating terrain and hill slope is essential for the establishment of tree plantation. It helps in arresting soil erosion during rainy season and survival of plants during summer. It was assessed average (index 2.70) at district level with 36.61, 34.82 and 28.57 percent plantation sites classified as good, average and poor respectively on the basis of SWCT adoption (Table 5). It was ranked good at Bhagwantpura, Bharari, Reaserch farm and Banguan in Badagaon block, Charora, Chamarua, Palida, Ghisoli, Badora, Bhagora and Naya khera in Babina Block, PWD building, Bangra and Katera in Bangra Block, Magerwara and Markuan road site in Mauranipur Block, Opara, Sultanpura, Bharatpura and Pipra road site in Chirgaon Block, Panari and Paresa in Moth Block.

C. Plant protection from animals: The protection of plants from grazing animals, both domestic and wild, is essential during the establishment phase. Therefore, it was considered as an important indicator which was found good (index 3-5) at most of the sites. For example near Narayanbagh and Vanguan, Company bagh and lakara in Badagaon, Charora, Badora, Foolpur and Nohra in Chirgaon, Khandarka, Dhawakar road site in Bangra,

Garotha and markua road site in Mauranipur, Opara, Fatehpur, Sultanpura, Khillabari, Bhagarua and Chelara in Chirgaon, Ghateshwar in Moth Block whereas Bhagwantpura, Hill behind GGIC road, Gughua, Palipahari in Badagaon Block, Palida, Badora and PWD-Babina in Babina, katera in Bangra, Magerwara, Kachnev, Magarpur and Sijari road site in mauranipur, Bujurg, Opara, bangara and Ranipurtgela road site in Chirgaon, Panari, Paresa in Moth was found average (2-3). At some places viz., road site plantation and plantation work done by Nagar Nigam Jhansi near Gwalior road was found in a bad shape (index upto 1). The study reveals that 31.25% sites were well protected where as there were no fencing or protection from animals at 7% sites (Table 5).

Table 4: Overall assessment of plantation work

Ranking	Score	No. of sites in %
Poor condition	< 15	2.68
Average condition	15 - 25	20.54
Good condition	25 - 35	51.79
Very good condition	> 35	25.00

D. Life saving irrigation: Though plantation work started during the rainy season, life saving irrigation was required for the establishment of tree plants more particularly on

hill slopes and undulating terrain with stony surface as the water holding capacity of soil is very low. The study revealed that it was ranked good (index 3-5) at Bharari farm and Company bagh in Badagaon, PWD-Building in Babina, Markua road site in Mauranipur, Sultanpura in Chirgaon, Average ranking (2-3) sites were Bhagwantpura, Near Narayanbagh Hill behind GGIC road, Navodaya Vidyalaya and Gughua in Badagaon, Charora, Chamarua, palida, Ghisoli, Badora, Bhagora, Babina-Tumka road Babina-Cantt, Guavali and Naya khera in Babina, PWD building, Bangra and katera in Bangra, Magerwara, Kachnev, Magarpur and Garotha in mauranipur, Bujurg, Opara, Luhari road, Lahargaon road and Fatehpur in Chirgaon, Panari and Ghateshwar in Moth. The study revealed that 30.36, 64.29, and 5.36 % sites were rated as poor, average and good respectively (Table 5) with district ranking as poor (index 1.9)

Table 5: Overall assessment of plantation indicators.

Indicator	Poor (%)*	Average (%)*	Good (%)*	Overall Score
Basin size	29.46	34.82	14.29	2.35
Soil-water conservation technique	28.57	34.82	36.61	2.70
Protection from animals	7.14	61.61	31.25	2.99
Life saving irrigation	30.36	64.29	5.36	1.99
LRU and Species selection	0.00	45.54	54.46	3.63
People participation and perceptions	14.29	75.00	10.71	2.50
Plant vigor	1.79	60.71	37.50	3.28
Plants Survival	5.36	82.14	12.50	10.58
Overall Score/ Rank				30.02

* Percentage of total number of sites selected

E. Selection of plant species according to land resource unit: For the establishment of tree plantation, especially in non-arable terrestrial ecosystem, it is necessary to select proper tree species for different land resource unit in view of difficult terrain and other edapho-climatic conditions. At many places this was not followed. It was expected that there will be emphasis on local tree species and preference could have been given to non-browsing tree species keeping in view the *Anna Pratha* practices followed in the region. The selection of tree species was ranked as good for 54.46% sites and average for the rest sites (Table 5). It was ranked good at Bhagwantpura, Bharari Research farm, Banguan, Near Narayanbagh, Palipahari Khajraha and Lakara in Badagaon, Charora, Chamarua, Palida, Ghisoli, Badora, Prithvipur, Foolpur, Naya kheda, Ganeshpura in Babina, PWD building and Khandarka in Bangra, Magarpur and Garotha-kakarbai road in Mauranipur, Opara, Fatehpur, Lahargaon and Luhari road site in Chirgaon, Panari in Moth, Gursarai,

Duri, Kudari and katharri in Bamaur, Pandawaha, Kachir and Gusarai road in Gursarai.

F. Peoples' participation and perception: The people's affinity was found high (index 3-5) at Charora and Foolpur in Babina, Magerwara and Garotha-kakarbai roadside villages in Mauranipur, Sultanpura and Opara in Chirgaon, Paresa and Ghateshwar in Moth and Kathari in Bamaur. In general the indices were found very high (4-5) at the sites owned by farmers and Common Property Land of villages. But around the Jhansi city (Gwalior road) people showed no affinity towards the plantation drive and even tried to break the fencing and put their animals in planting sites for grazing.

G. Plant vigour and health: The health conditions of tree saplings affect the percent rate of establishment and survival. It is evident from table 5 that 37.50, 60.71 and 1.79 percent plants saplings were good, average and poor respectively. The study revealed that it was ranked good at places such as Bhagwantpura, Bharari farm, Banguan, Navodaya Vidyalaya, Gughua and Birahata Forest Block in Badagaon, Chamarua, Palida, Ghisoli, Foolpur, Badora, Bhagora, PWD-Babina and prithvipur in Babina, PWD building, Bangra and Khandarka in Bangra, Magerwara and Garotha in Mauranipur, Opara, Fatehpur, Sultanpura and Bharatpura in Chirgaon, Panari and Ghateshwar in Moth, and average ranking (index 2-3) sites were Bhagwantpura, Narayanbagh, Banguan, hill behind GGIC road and Rakshemai ki pahari in Badagaon; Charora, Chamarua, Badora, Babina-Talbehat, Babina-Tumka road and Ganupura in Babina Block, PWD building, Katera and Dhawakar road site in Bangra, Magerwara, Kachnev, Magarpur and Sijari road site in Mauranipur, Bujurg, Opara, Bangara, Khillabari and Luhari road site in Chirgaon, Paresa and Gursarai-kotra road in Moth.

H. Survival of plants: One of the most important objectives of the monitoring programme was to search out the percentage of survived tree plants. The survival of tree plants depends upon many factors as explained above. The SCM index ranging between 1 and 15 was assigned to give extra weightage to the percentage of survived as of tree plants. Overall plant survival in Jhansi district was found good (score 10.58). On the basis of percent plant survival 12.50, 82.14 and 5.36 percent sites were classed as good, average and poor respectively (Table 5). It was ranked good (index 9-15) at Bhagwantpura, Bharari farm, Banguan, Navodaya Vidyalaya, Gughua and Birahata Forest Block in Badagaon, Charora, Chamarua, Palida, Ghisoli, Badora, Bhagora, Babina-Cantt., Guavali and Naya khera in Babina, PWD Building, Bangra and Katera

in Bangra, Magerwara, Kachnev, Markua road site, Magarpur and Garotha in Mauranipur, Bujurg, Opara, Fatehpur, Bangara, Sultanpura in Chirgaon, Paresa, Panari and Ghateshwar in Moth, Near Narayanbagh in Jhansi.

2. Assessment of special plantation drive in different blocks

A. Badagaon: More than 20 sites were covered in Badagaon Block for the assessment of plantation work. In this block the plantation work was found good (index 28.21 out of 50). The agencies involved in the plantation works were forest department, NREGS etc. Average performance was noticed in Basin size (2.24), Soil-water conservation technique (2.85), Life saving irrigation (2.05) and People's affinity towards SPD was 1.95 whereas it was good in Protection from animals (3.00), Land Resource Unit and Species selection (3.52), Plant vigour (3.09) and Percent survival of plants (9.50). In this block, 3 sites located at Research Farm Bharari, Company Bag and Navoday Vidyalaya were rated as very good.

B. Babina: Twenty seven sites were evaluated in Babina block and overall performance score was 31.91 (out of 50) and rated as good. The agencies involved in the plantation works were Forest Department, NREGS, Electricity Board, Social Forestry, Nagar Panchayats, Irrigation Department, PWD, BDO, Gram Panchayat etc. Average performance was found in indicators viz., Basin size (2.67), Soil-water conservation technique (2.85), Life saving irrigation (2.30) and People's affinity towards SPD (2.44) whereas it was good in Protection from animals (3.04), Land Resource Unit and Species selection (3.96), Plant vigor and (3.96) and Percentage plants survival of (11.40). The planting methods and over all plant survival was found in a very good condition (37.5 to 39.5 out of 50) in Sukwa, Badora, Nai Pali, Guavali, Naya Kheda and Ghisoli villages.

C. Bangra: The plantation sites in Bangra Block are located in remote areas in highly undulating terrain. The sites situated along the NH76 and other pakka roads were in good condition (index 32.5 of 50) whereas overall score was 31.42. Average performance was noticed in Basin size (2.33), Soil-water conservation technique (2.83), Life saving irrigation (2.17) and People's affinity towards SPD was 2.67 whereas it was good in Protection from animals (3.00), Land Resource Unit and Species selection (3.67), Plant vigor (3.50) and Percent survival of plants (11.30). The best performance was noticed around the PWD Rest House. The plantation was found in good condition at Katera and Khandarkar. In general, the

uncultivable lands were with red soil having very low water holding capacity. There was need to irrigate the tree plants during the summer.

D. Mauranipur: The soil of Mauranipur block is relatively better than Bangra. About 217,000 tree plants at 13 sites were verified and overall performance was rated as good (30.00). Average performance was noticed in Basin size (2.31), Soil-water conservation technique (2.77), and People's affinity towards SPD (2.54) and Protection from animals was 3.00 whereas it was good in Land Resource Unit and Species selection (3.67), Plant vigor and (3.50), Percent survival of plants (11.30) and Life saving irrigation (2.17).

E. Chirgaon: The overall plantation work in Chirgaon block was rated as good (score 32.28 out of 50). Most of the plantation sites in the block were in good to very good condition. The soil fertility status and irrigation facility as well as relatively better affinity of rural people towards the plantation drive was the main reason of success. Average performance was noticed in Basin size (2.67), Life saving irrigation (2.00), Protection from animals (2.94) and Soil-water conservation technique (2.89) whereas it was found good in Protection from animals (3.40), Land Resource Unit and Species selection (3.67), Plant vigor (3.44) and Percent survival of plants (11.3 out of 15).

F. Moth: The soil of Moth Block is very good for plantation work especially in village Ghateshwar, Panari and Paresa. In this block the overall plantation work was found very good (at about 33.17 out of 50). Good performance was noticed in Basin size (3.00), Soil-water conservation technique (3.16), Protection from animals (3.00), Land Resource Unit and Species selection (3.33), People's affinity towards SPD (3.17), Plant vigor (3.66) and Percent survival of plants (12 out of 15) whereas it was found poor for Life saving irrigation (1.83).

G. Bamaur: Bamaur was rated as average (score 29.59 out of 50). Good performance was recorded in Protection from animals (3.45), Land Resource Unit and Species selection (3.91), Plant vigor (3.36) and Percent survival of plants (10.1 out of 15) whereas it was found average in Soil-water conservation technique (2.36), Life saving irrigation (2.00), People's affinity towards SPD (2.55) and poor for Basin size (1.82).

H. Gursarai: The overall plantation work in Gursarai Block was rated as average (score 23.92 out of 50). Village Kachir, Londi and Panwaha were found in good condition. Good performance was recorded in Land Resource Unit and Species selection (3.50) and Plant Vigor (3.00)

whereas average performance was recorded in Protection from animals (2.5), People's affinity towards SPD (2.00) and Percent survival of plants (8.58 out of 15) and poor performance in Basin size (1.50), Soil-water conservation technique (1.50) and Life saving irrigation (1.33).

3. Forage Production from selected plantation sites

Out of 112 sites, 15 sites, which were well protected (PFA-SCM 3-5), were selected from different blocks and different Land Resource Unit. The total area under these 15 sites was 575 ha and planted with about six lakhs tree plants. Random quadrant (1x1 m) samples for estimating forage yield were taken from 3rd week of August to 2nd week of September 2008. The forage yield (DMt/ha) from bunds and field were 2.06, 1.07 respectively with average yield of 1.13. Reseeding of suitable grass / legume species on bunds during monsoon might be the reason of higher production of forage on bunds.

Conclusions and Recommendations

Based on the stratified random clusters, total 112 sample sites were selected from all the 8 blocks of the district. The salient findings of this monitoring and evaluation programme are listed below:

The overall performance of Special Plantation Drive in Jhansi district was found in good condition. The SCM based indicators selected for the assessment of plantation drive viz., Land Resource Unit; Species selection; Plant vigour; health and percent survival of plants were assessed as good whereas basin size, soil-water conservation technique, protection from animals and people participation and perceptions was rated as average. The main reason of plant mortality and low survival rate was lack of life saving irrigation. The study reveals that overall plantation work was good at 51.79% plantation sites. During the establishment, phase protection of tree plants from grazing animals is essential but adoption of this technique was found average in the study area. The planting agencies were not much sincere about the life saving irrigation to the plants during the establishment phase. People's awareness about the SPD and their affinity towards the tree plantation was

average. The percent survival of plants was recorded as good in 12.5% sites, average in 82.14% sites and poor in only 5.36% sites.

To sustain this survival rate during summer months, the efforts should be on proper irrigation and watering during dry months and on conserving the moisture through mulching. To achieve the highest canopy cover it is necessary to fill the gap with new tree plants in the next monsoon seasons. It is essential to educate the rural people about the short term and long term benefits of this SPD. This will not only help the tree cover increase in the district but will enrich the biodiversity and carbon pool and provide tree forage to livestock which is deficit in the district.

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References

- Singh J. P., D. Saha and R. K Tyagi. 1997. "Grazinglands Inventory and Monitoring for Biomass Production and Eco-development Using cartographic and Remote Sensing Techniques" *Indian Cartographer*, Vol. 17:213-218. Hyderabad.
- Singh J. P., N. S. Ekka, T.A. Khan, P. N. Dwivedi and B. K. Trivedi. 2007. Assessment of forage availability from rangelands of Bundelkhand region using GIS and remote sensing techniques. *Range Mgmt. & Agroforestry*. 28: 66-68.
- Pathak P. S., J. P. Singh, P. Sharma, K. K. Singh, P. N. Dwivedi and J. B. Singh. 2005. *Bundelkhand region: Agricultural Perspectives- Status, Constraints and Prospects*. October 2005. IGFR, Jhansi.
- Singh J. P., P. N. Dwivedi, N. S. Ekka, R. K. Agrawal and S. Radotra. 2009. Use of remote sensing in assessing forage availability. In N. Das *et al.* ed. *Forage for sustainable livestock production*. Satish Serial Publishing House, Delhi. 51-66.
- Singh J. P., P. N. Dwivedi, and N. S Ekka. 2001. Application of remote sensing and GIS techniques in assessing forest cover and impact of forest grazing. *Indian Cartographer*. 21: 142-45.