WATERSHED APPROACH IN RAINFED AFFORESTATION

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Introduction

Around 73 per cent lands in India are dependent on rains for developing productive system. These rainfed areas are characterised with limited seasonal rainfall with erratic behaviour (Bharad *et al.*, 1991). Most of the afforestation programmes are dependent on seasonal and erratic rainfall. During rainy season, the vegetation suffers from water deficit situation at upper part and due to prolonged wet conditions on lower parts of the toposequence at a time. This situation is the result of the fact that most afforestation programmes are not planned on the basis of watershed. Because of this, the upper parts are eroding rapidly and resulting in poor vegetation cover. Poor vegetation cover in turn again results in lower infiltration, higher surface run-off of rain water and severe erosion. Thus, the cycle is rotating in the other way than the desired one. In order to turn this cycle in the right direction, watershed is accepted as a basic unit at all levels for resource management. For successful rainfed afforestation, the objective would be *in-situ* conservation, development and utilization of water, soil and vegetation resources. As the water from outside can not enter a watershed, it is important to harvest and use every drop of water for establishment of seedlings in any afforestation programme.

All afforestation programmes helps in soil and moisture conservation, but it is considered that greater benefit would accrue if the programmes are carried out taking watersheds as unit. Watershed approach includes land use, conditions of erosion, soil depletion, soil fertility, productiveness and the people with their community interests. For proper water management it is important to work out systematic use of water from the top of each watershed to the bottom.

A Case Study in Amravati Division

In Amravati Division (Maharashtra) an afforestation programme was designed based on watershed as unit. Amravati is having around 1,600 ha of reserved forest within the city limit. Excessive grazing and removal of young trees for fuelwood leads to denudation of hills. Lack of vegetal cover leads to increase surface run-off, which in turn increases the soil erosion.

In Amravati, annual rainfall is around 500-600 mm. Besides this total rainfall is distributed during June to September (35 to 40 days). Hence around 3/4th of the year is totally rain free and dry. Total cattle population of around 10,000 and sheep and goat population of 12,000 are dependent on the degraded forest area in and around the city.

Methodology

Out of the total 1,600 ha of degraded forest land within city limit of Amravati, 1300 ha was selected for integrated

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development based on the sound watershed management technique. It was proposed to treat the area in phased manner and 700 ha area was tackled during initial three years.

Total area was divided into 15 micro-watersheds and each micro-watershed was divided into three types of area depending on degree of slope and soil quality as follows :

(i) *Run-off Zone* : Area above 15° slope, completely eroded soil layer with exposed hard murrum and boulders; no trace of grass and shrubs. In this zone run-off rate is very fast.

(ii) *Percolation Zone* : Area having slope between 3° to 15°, eroded soil with exposed boulder and soft murrum, presence of local grass and shrubs suppressed by excessive grazing. In this zone run-off rate is moderate.

(iii) *Storage Zone* : Area having insignificant slope (below 3°), good soil, often black cotton soil, grass and shrubs are common, rooted stocks of *Acacia nilotica, Acacia leucophloea, Acacia catechu, Butea monosperma* are common, but suppressed by continuous hacking for fuelwood and by excessive grazing. In some parts, *Lantana camara* was prominent. In this zone run-off is slow and eroded soil from above two zones get deposited.

In the total watershed around 25% area falls under run-off zone, 65% area falls under percolation zone and 10% area falls under storage zone.

Following treatments were given to various zones :

Run-off Zone : In this type of area, continuous trenches (60 cm wide and 30 cm deep) along the contour were dugout at 8 m horizontal intervals and in between two continuous trenches, 4 m long trenches with 2 m gap were dugout. In all around 2,000 running meters of trenches were dugout per hectare. Better soil of top layer was heaped in upper part and boulders and murrum in lower part of the trench. Before monsoon starts available good soil from upper part is used for filling of trenches at 2 m interval in the form of mound of 45 cm x 45 cm. Soil mound is used for planting of seedlings and unfilled gap between two mound acts as water absorption trenches. This technique is good in run-off zone because sufficient quantity of soil is not available to fill up the whole length of trenches, and because of above technique large volume of water can be absorbed in unfilled trenches. Lower heap of boulders and murrum are undisturbed which act as barrier for water run-off. Along the lower side of trenches on mound, *Stylohamata* seeds were sown. Hence Continuous Contour Trenches (CCT) act as water absorption trench and a vegetative barrier is created to prevent the run-off of water in steep slopes.

Percolation Zone : Trenches were dug in same pattern as mentioned in run-off zone. A total of 2,000 running meters of trenches were dugout. But the trenches in these area were half filled throughout the length in lower side of the slope with better available soil from upper part. Lower heap of boulders and murrum are undisturbed and used for sowing of *Stylohamata* and local grass seeds. Half filled trenches were used for planting seedlings at 1 m interval. Unfilled half trenches were used for water absorption purpose to prevent run-off and soil erosion.

In Storage Zone : In this zone run-off is minimum and so 2,500 pits of 45cm x 45cm x 45cm were dug per hectare with spacing of 2m x 2m. After filling the pits with good soil 2,500 seedlings were planted per hectare in conventional way.

Treatment of Gully and Drainage Line : Following treatments were given depending on the centre depth of drainage line :

(i) Small gullies upto 1 m deep were checked with dry rubble plugs and brushwood structures. Brushwood obtained during site clearance were also used to check the small gully.

(ii) Medium size drains (Nalas) upto 3 m deep were treated with dry rubble check dams and "gabien structures" (dry rubble bunds stabilized by wrapping wiremesh all around). Gabien structures were constructed at the places where water force was high.

(iii) In large nalas more than 5 m deep earthen bunds were prepared with proper side drain (water weir) so as to store excess water and increase the percolation. *Vetiver* sp. (Khus grass) were planted on the bunds to stabilise the structure.

Soil analyses of different zones were carried out before and after treatment of watershed in 1990 plantation. Throughout the watershed area eleven open wells 10 m deep were dugout to facilitate monitoring of water table and also used supply water to labourers throughout the year.

Rooted Stock Management : During site clearance enough care was taken to boost the growth of stunted rooted stock of *Acacia* sp. *Butea* sp. and other local trees and shrubs species. Singling operation and coppicing of suitable species were carried out.

Observation and Discussion

Water conservation : In the various zones of watershed water retention capacity are as follows :

(i) Run off Zone :

Total volume of CCT (2000 RMT)	= 360 m^3/ha
Total volume of 1000 planting mound (45 cm x 45 cm x 30 cm)	= 60.75 m^3/ha
Net available space for water absorption	= 299.25 m^3/ha

(ii) Percolation Zone :

Total volume of CCT (2000 RMT)	= 360 m^3/ha
Half volume is filled for planting	= 180 m^3/ha
Net available space for water absorption	= 180 m^3/ha

(iii) Storage Zone :

Total volume of each pit (45 cm x 45 cm x 45 cm)	= 0.091 m^3
After filling 30% capacity	= 0.091 x 0.3
Only used	= 0.027 m^3
Net available space for	= 0.027 x 2500
Water absorption/ha (2500 pits)	= 67.5 m^3

Reason for Differential Treatment in Watershed Area

Different zones in Watershed are differing in respect of water holding capacity, run-off rate, soil quality and nutrient contents. In view of the above facts different treatments are given with respect to water absorption structures and number of seedlings planted.

In run-off zone which comprises 25% of the watershed area, run-off rate is very high and moisture retention capacity is low and soil quantity is very less, so only 1,000 seedlings are planted to avoid undue root competition. At the same time layout in the run-off zone is such that it can hold the maximum rainfall (300 m^3/ha) in any day and can completely prevent run-off and soil erosion. In turn the continuous contour trench avoid run-off loss of water and soil which can not be prevented by staggered trench or pit layout due to presence lateral and vertical slopes. Continuous Contour Trench structure also increases the percolation which in turn enhances sub-surface flow and ground water recharge (Bharad *et al.*, 1991).

In percolation zone which comprises 65% of the watershed area, soil quality is better and quantity is also more, so 2,000 seedlings were planted to use the optimum land potential. In this zone half filled trench is sufficient to hold the average rainfall (180 m^3/ha) and to prevent soil erosion. In this zone also percolation increases and which in turn increases sub-surface flow and ground water recharge.

In storage zone which comprises 10% of the watershed area, run-off rate is very low and soil quality is very good so in order to use the full potential around 2,500 seedlings were planted. Besides this due to increase in sub-surface flow, water availability in this zone is for longer period. Hence no water absorption structure is prepared except the digging of planting pits (45 cm x 45 cm x 45 cm) which can hold 67.5 m^3/ha of water. To avoid accumulation of excess water and temporary water logging during heavy rain, this zone allows excess water to flow towards the drainage line. Water logging in the storage zone often damages the seedlings during heavy rain. Any excess water from this zone can be accommodated in drainage line and stored in structures like gully plug, check dams, gabien structure and nala bunds which enhance percolation and recharge of ground water. Moreover because of dynamic nature of water there is sub-surface flow of recharge towards the storage zone and drainage line.

Recharge of Ground Water

Water table data collected from 11 dug wells is tabulated in Table 1. It is evident from the data that water table increases in all the wells. Hence the systematic

Table 1

Water level in monitoring well during summer

Zone/ Well No.	Water level before watershed treatment (m) May - 1990	Water level one year after watershed treatment (m) May - 1991
Percolation Zone		
1	0.90	1.20
2	0.60	0.90
3	0.90	1.00
4	0.65	0.90
5	0.55	0.90
6	0.90	1.10
7	0.85	1.00
8	0.85	1.15
Storage Zone		
9	1.50	1.80
10	1.50	3.00
11	1.60	2.40

Table 2

Average height (m) of some important species as recorded in October, 1993

Species	1990 Plantation			1991 Plantation			1992 Plantation		
	Run-off zone	Perco-lation	Stor-age zone	Run-off zone	Perco-lation zone	Stor-age zone	Run off zone	Perco-lation	Stor-age zone
Ailanthus excelsa	2.90	3.20	5.12	1.80	2.50	3.70	1.12	1.50	1.80
Azadirachta indica	1.78	3.38	5.10	1.50	2.60	3.75	1.23	1.75	2.36
Albizia lebbek	1.10	3.80	5.40	1.00	2.40	3.80	0.90	1.15	2.00
Dalbergia sissoo	1.10	3.30	6.00	1.00	2.45	4.00	0.70	1.60	3.60
Inga dulcis	0.90	2.60	4.50	0.75	1.75	3.00	1.50	1.70	2.07
Pongamia pinnata	1.50	3.10	4.80	1.20	2.00	2.80	1.00	1.60	2.00
Gmelina arborea	1.40	4.00	6.50	1.00	2.80	4.60	0.90	2.00	3.50
Tectona grandis	1.00	3.90	4.60	0.50	2.50	2.70	0.20	0.85	1.50

treatment of watershed in afforestation programme can help in recharging the depleting ground water resource.

Results of Plantation

Table 2 shows the height growth of some of the species in 1990, 1991 and 1992 plantation as recorded in October 1993. It is clear from the data of height growth that growth in run-off zone is less as compared to percolation zone and storage zone. Growth in storage zone is best in all the plantations. Height growth in run-off zone is slow. But in this zone lot of grass and other shrubs appeared by natural regeneration. Height growth of seedlings are vigorous in percolation and storage zone.

Performance of various species in different zones are different. In run-off zone *Ailanthus excelsa* and *Azadirachta indica* show best height growth whereas in percolation zone *Gmelina arborea, Tectona grandis* and *Albizia lebbek* show best height growth. In storage zone *Gmelina arborea* and *Dalbergia sissoo* show best height growth.

As a whole due to extensive soil and moisture conservation works, there is extremely good growth of all species in total watershed area. Average survival percentage is more than 90 in all the plantations.

Extensive rooted stock management has resulted in vigorous growth of natural species of trees and shrubs.

Grass Production

Integrated afforestation programme, soil and moisture conservation has resulted in to increased grass production in the area. In order to involve local people in protection of watershed, grass was distributed free of cost on cutting basis. All local persons were allowed to cut and to collect grass on head load basis for own bonafide cattle or for sale in market. Because of heavy demand for grass in city, many unemployed youth

Table 3

Month-wise free grass distribution from treated watershed

Month	Head loads of grass distributed			
	1990	1991	1992	1993
July	6500	8000	7500	7900
August	8600	9500	8600	8000
September	11000	10600	13000	13500
October	9000	13000	14500	13800
November	5600	9400	11000	—
December	3000	6000	10000	—
January	3000	3500	5500	—
February	1400	2500	500	—
Total	48100	62500	70600	43200
Estimated cost* (@of Rs. 20/- head-load of grass) Rs.	9,62,000	12,50,000	14,12,000	8,64000
Value of grass produced/ha Rs.	1374	1786	2017	—

Note: (i) Each headload wt. (kg) = 35 to 40
(ii) Price of each headload in Amravati = Rs. 15 to Rs. 25/-
(iii) Average price/headload = Rs. 20/-
(iv) Total area of Watershed = 700 ha

earned upto Rs. 50/- per day by selling grass in Amravati City. Results of grass distribution are shown in Table 3. Rough estimates of value of grass distribution in year 1990, 1991 and 1992 are Rs. 9,62,000, Rs. 12,50,000 and Rs. 14,12,000 respectively from the 700 ha of the watershed. Till October 1993 grass worth Rs. 8,64,000/- was distributed free of cost. Because of full grass cover in total watershed run-off is reduced substantially (Rege, 1959; Shankarnarayan and Shankar, 1984).

Soil Composition

Table 4 shows the change in soil composition after plantation and watershed treatment. Most prominent change observed is increase in organic carbon, potash and phosphorus. It is clear that the quality of soil has improved in all three zones; humus also increased significantly in the area.

In view of the above facts it is evident that all rainfed afforestation programmes should be undertaken on the sound watershed principles, taking into consideration the land, water availability and people's need. Planning should be made from top to the bottom of the watershed. Different treatment as per the requirement of the site should be given keeping in mind the total available rain water, run-off rate, slope and soil quality.

Table 4

Some of the soil parameters before and after watershed treatment (in 1990 Plantation)

Zone/ Soil Parameter	Before treatment	After one year of treatment	After two year of treatment	After three year of treatment
Run-off Zone :				
pH	7.90	6.60	6.60	6.60
E.C. (mmhos/cm^3)	0.10	0.10	0.10	0.10
Organic Carbon (%)	0.30	0.69	0.85	0.95
Available Phosphorus (kg/ha)	19.00	28.00	28.00	29.00
Available Potash (kg/ha)	170.00	227.00	240.00	250.00
Percolation Zone :				
pH	7.80	7.10	6.90	7.20
E.C. (mmhos/cm^3)	0.10	0.10	0.10	0.10
Organic Carbon (%)	0.38	0.75	0.85	0.95
Available Phosphorus (kg/ha)	35.00	55.00	68.00	72.00
Available Potash (kg/ha)	204.00	272.00	281.00	304.00
Storage Zone :				
pH	7.40	7.20	6.80	6.90
E.C. (mmhos/cm^3)	0.10	0.10	0.10	0.10
Organic Carbon (%)	0.52	0.87	0.95	1.00
Available Phosphorus (kg/ha)	46.00	67.00	85.00	85.00
Available Potash (kg/ha)	227.00	284.00	352.00	370.00

SUMMARY

In India most of the Afforestation Programmes are rainfed. In order to make the successful afforestation in degraded forest it is important to treat the area on the basis of watershed unit. Instead of carrying out afforestation of isolated patches, it is suggested to treat whole watershed depending of the type of area, soil status, slope and water retention capacity. During the rainy season, the vegetation suffers from water deficit situation at upper part, and due to prolonged wet condition on lower parts of the toposequense at a time. In a case study of Amravati, total 700 ha area was treated after dividing it into small micro-watershed and has shown excellent result. *In-situ* conservation of moisture in watershed leads to luxurious growth of vegetation and successful afforestation. Suitable conservation and storage structures at appropriate locations in micro-watershed lead to recharge of ground water. Increase in ground water table is being reflected in 11 dug wells in the watershed.

वर्षापोषित वन रोपण कार्य में जलविभाजन दृष्टि

मोहन झा

सारांश

भारत में अधिकांश वन रोपण कार्यक्रम वर्षा पोषित है । व्याहसित वन क्षेत्रों में वन रोपण को सफल बनाने के लिए महत्वपूर्ण यह है कि जलविभाजन इकाइयों के आधार पर उस क्षेत्र का उपचार किया जाए । अलग-अलग पड़े एकाकी टुकड़ों में वनीकरण के बजाए सुझाया जाता है कि क्षेत्र के प्रकार, मृदा स्थिति, ढाल और जलधारण क्षमता के अनुसार पूरे क्षेत्र का उपचार किया जाए । बरसात में ऊपरी भाग में पानी की कमी और उसी समय स्थलानुक्रम के निचले भागों में लम्बे समय तक आद्रता बनी रहने के कारण कष्ट झेल रही वनस्पतियां होती हैं । अमरावती में किए गए एक विशेष अध्ययन में 700 हेक्टेयर कुल क्षेत्रफल का उपचार उसे छोटे-छोटे अणुजल-विभाजनों में बांटकर किया गया जिसके परिणाम बहुत बढ़िया रहे । जल विभाजन में आद्रता को वहीं की वहीं संरक्षित करके रखने से भरपूर वनस्पति वृद्धि और सफल वनीकरण होता है । अणुजल-विभाजनों में उपयुक्त स्थानों पर उपयुक्त संरक्षण और भंडारण संरचनाएँ बनवाने से भूमि जल का पुनर्भरण हो जाता है । भूमि जल पटल का ऊंचा उठना जलविभाजन में खोदे गए 11 कुंओं में दिखाई पड़ रहा है ।

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