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ORIGINAL ARTICLE

Environmental Benefits by Implementation of Agroforestry Systems for Garhkundar-Dabar Watershed Central India-A Case Study

K. N. Singh *1 , R. Singh2 , D. Khalkho3 , Anil Kumar Singh4 , Amit Dahate 3 and M. P. Tripathi 3
1, IGKV, Raipur-492012, Chhattisgarh, India
2 Principal Scientist, ICAR-CAFRI, Jhansi-284003, Uttar Pradesh, India
3 Department of Soil and water Engineering, IGKV, Raipur-492012, Chhattisgarh, India
4 Scientific Officer, (ICRISAT), Hyderabad-502324, India
*Corresponding Author-Email: knidhansingh@gmail.com

ABSTRACT
This study has conducted on selected households to analyze the environmental benefits by adopting of agroforestry in Garhkundar-Dabar watershed. Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system. The main purpose of this study is to understand the impacts of agroforestry on environment of Garhkundar-Dabar watershed, central India. This study interpretates the environment benefits, farmers willingness, runoff reduction, improvement fertility of soil and climate change of study area.
Key words*: Watershed, agroforestry adoption, Farmer's perception, Land use, environment and livelihood security*

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INTRODUCTION

Although systems integrating trees and agriculture have been practiced for thousands of years, the term 'agroforestry' was first coined in 1977 [4]. In its simplest form, agroforestry can be described as "growing trees on farms" [28]. "Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system" [16]. This represents a concept of integrated land use that combines elements of agriculture and forestry in a sustainable production system. The emphasis here is on managing rather than reducing complexity. Agroforestry uses the natural woodland ecosystem as a model to create "a dynamic, ecologically-based, natural resources management system" [15]. Key characteristics that distinguish agroforestry systems from agriculture and forestry include greater structural and functional complexity, an emphasis on multipurpose trees, and the production of multiple outputs balanced with protection of the resource base [19]. The World Agroforestry Centre (ICRAF) identified six ways that agroforestry can contribute to achieving the Millennium Development Goals of combating hunger, poverty, disease, illiteracy, environmental degradation, and discrimination against women [10].

1.Eradicate hunger using agroforestry methods of soil fertility and land regeneration.
2.Reduce poverty using market-driven, local tree cultivation systems to generate income and build assets.
3.Advance the health and nutrition of the rural poor.
4.Conserve biodiversity using agroforestry-based integrated conservation-development solutions.
5.Protect watershed services and enable the poor to be rewarded for providing these services.
6.Help the rural poor to adapt to climate change and benefit from emerging carbon markets. [10].

Absolute poverty, high livestock and human population pressure and degradation of production base are some of the problems defying solution in most developing countries including India in these regions [9]. In India, 65% of the 142 million hectares of arable area is rainfed with very low productivity (1–1.5 Mg/ha), largely due to low rain water-use efficiency (35–45%) for crop production. Integrated watershed management has been a prominent approach for resource conservation and livelihood security in these areas. Meta analysis of 627watershed case studies was done under a comprehensive assessment of watershed programs in India by ICRISAT led consortium. The agroecosystem of Bundelkhand is characterized by undulating and rugged topography, highly eroded anddissected land, poor soil fertility, scarce groundwater resource, erratic rainfall leading to frequent droughts, poor irrigation facilities, heavy biotic pressure on forests, inadequate vegetation cover and frequent crop failures resulting in scarcity of food, fodder and fuel [20]. The introduction of agri-environment schemes to encourage farmers to follow good environmental practices through agroforestry. The household requirements like fruits, fodder, fuel, fibre etc. have been fulfilled by agroforestry traditionally. Tree crops have been widely introduced as a way to re-establish a protective cover in environmentally fragile ecosystems [1, 21] and restore the soil fertility status. Environmental conditions have been balanced through agroforestry by way of microclimate moderation and degraded land rehabilitation and simultaneously enhances productivity. Besides providing employment to millions of people, agroforestry also supplies over 95% of fuel wood and 40% of the forest products. Organized agroforestry research is now more than sixty years old and despite some impressive scientific and technological advances over the last four decades, agroforestry rural development projects have experienced uneven success rates in many parts of the world due to inadequate adoption rates and/or abandonment soon after adoption.

Here, we presents the study of agroforestry adoption for Garhkundar-Dabar watershed, of Yamuna basin situated in Bundelkhand region of Central India which interpretates the environment benefits, farmers willingness, runoff reduction, improvement fertility of soil and climate change of study area. Agroforestry interventions in watershed development programswas initiated in Garhkundar-Dabar watershed of Bundelkhand under semi-arid region of central India.

MATERIAL AND METHODS

General Description of the Study Area

Study was carried out at Garhkundar-Dabar (GKD) watershed is located between 78° 52' 39" to 78° 54' 44" E longitude and 25° 26' 23" to 25° 28' 32" N latitude with an altitude varying from 230 to 280 m above mean sea level (MSL) in the Tikamgarh district of Madhya Pradesh, India. This watershed is a part of the Betwa river catchment of Yamuna sub-basin.

The agro-climate of the watershed is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Mean annual temperature ranges from 24 to 25 ^{0}C. The mean summer (April-May-June) temperature is 34 ^{0}C which may rise to a maximum of 46 to 49 ^{0}C during the month of May and June. The mean winter temperature (December-January-February) is 16 ^{0}C which may drop to 3-5 ^{0}Cin December and January. The mean annual relative humidity varies between 40 to 60 per cent. Rainfed agro-ecosystem occupies the major cropped areas of the Bundelkhand region. Although agriculture is the mainstay of the people, only 20 per cent of the net sown area is irrigated.

The annual rainfall of the Bundelkhand region varies from 800 to 1300 mm, about 90% of which is received during South-West monsoon period (Singh et al. 2002). The geology of the study area is dominated by hard rocks of Archaen granite and gneiss and largely composed of crystalline igneous and metamorphic rocks, and aquifers are either unconfined or perched, having poor storage capacity (porosity of 0.01-0.05 %). In such hard rock aquifers with poor transmissibility, shallow dug wells of 5 to 15 m depth are only primary source of water for domestic and agricultural use in this region. Due to undulated topography, poor groundwater potential, high temperature, poor and erratic rainfall, agricultural productivity in this region is very poor (0.5-1.5 t ha^{-1}). The length of growing season in Bundelkhand ranges between 90 to 150 days depending upon rainfall and temperature regimes. Low rainfall and drought are common features. The soils of the watershed are shallow (10-50 cm), raddish to brownish red in color(Alfisols and Entisols) which is characterized by coarse gravelly and light textured with poor water holding capacity. Nearly 30% watershed area is under agricultural use and rest is covered by degraded forest, wasteland and scrub land.

Data collection

Augment of agroforestry development, almost 191 farm families of the watershed were contacted and encouraged to adopt agroforestry on their lands. The data was collected from 80 farmers (42% of total households in the watershed) representing all caste, creed, religion, gender and land holding class. The data for willingness to adopt agroforestry, system of plantation, motivating and inhibiting factors, etc. were collected through personnel interview in the study area.

RESULTS AND DISCUSSION

Integration of trees in farming systems- farmer's perceptions: Farmer's willingness to adopt fruit based agroforestry system increased from zero to 45% at before and after extension and just 5% for timber. Even after three years of constant efforts and persuasion nearly half of the population did not accept incorporation of trees on their farm lands (Table 1). Further, for fruit trees, nearly 44% of the farmers preferred boundary plantation followed by intercropping (34%) while in case of timber trees, boundary plantation was preferred by 52.5% farmers followed by block plantations (30%). None of the farmers was ready to plant timber and forage trees in their farm in intercropping plantation method and preferred block plantation for them on degraded/waste lands only (Table 2).

Table 1: Farmers willingness to plant trees on croplands (N=80)

Type of tree	before extention		after extension	
	N	(%)	N	(%)
Fruit	18	22.5	36	45
Timber	4	5.0	4	5
Not Willing	58	72.5	40	50

Table 2: Preferred system for tree plantation (N=80)

System preferred	Fruit		Timber		Forage	
	N	(%)	N	(%)	N	(%)
Boundary plantation	35	43.75	42	52.5	20	25
Intercropping	27	33.75	-	-	-	-
Block plantation	5	6.25	24*	30*	48*	60*
Around habitat	13	16.25	14	17.5	12	15

Farmers preferred fruit crops over others because of their economic value and ability to provide assured income even in drought years. Fruits can be sold in the local weekly markets even in smaller quantities to get regular income. The findings of Banninster and Nair (2003) that different farmers consider trees differently depending upon how they fit into their farm-family strategy and that farmer make decisions about tree culture based on house hold and field characteristics are confirmed during the present investigation. Despite of low agroforestry adoption, nearly 41% of the farmers considered it as an efficient land use system (Table 3).

Environmental benefits of agroforestry

Agroforestry protects the environment and providing a number of ecosystem services with integrating trees into farming system.The impact of agroforestry on the environment occurs as on soil structure and quality to impacts on the environment and society at regional or global scales.

Table 3: Farmers motives for agroforestry adoption(N=80)

Motive	Number	Frequency (%)
Efficient land use	33	41.25
High production and income	25	31.25
Risk proof land use	10	12.50
Self sufficiency	8	10.00
Protection from hot and cold winds	4	5.00

Soil

Soil management is a key feature of agroforestry systems, and in both tropical and temperate climates, agroforestry systems are designed and implemented to counter soil erosion and degradation, and improve soil quality and health.

Erosion

Croplands and grasslands replaced the natural forest and scrublands resulted in increased run-off and accelerated erosion in many agricultural areas. Structural stability of soil increased, tree roots can enhance water infiltration and improve water storage by increasing the number of soil pores. Macropores works as channel surface water flow and allow air and moisture to move into the soil thus risk of soil erosion reduced and tree roots and trunks act as a barrier to reduce runoff and sediment.

Fertility

When nutrients run away from soil horizons by tree roots and returned to the soil through leaf fall, then agroforestry systems helpful to enhance the soil nutrients and reduce reliance on external inputs. For example, leaf fall from 6 year old poplars resulted in mean soil nitrate production rates in the adjacent crop-alley up to double that compared to soils 8.0 to 15.0m from the tree row, and nitrogen release from poplar leaf litter was equivalent to 7kg N ha-1 yr-1 [24]. Relatively few of the 650 woody species that are able to fix atmospheric nitrogen occur in temperate regions; of these black locust (Robinia), mesquites (Prosopis), alder (Alnus) and oleaster (Eleagnus) have been investigated for their nitrogen-fixing potential [16]. Significant transfer of fixed nitrogen to crops has been observed in a study which showed that 32 to 58% of the total nitrogen in alley-cropped maize came from nitrogen fixed by the adjacent red alder (Alnusrubra) [12, 13].

Water

Agroforestry changed the hydrological cycles via changes in soil erosion, evapotranspiration rates and runoff, modification of river flow and irrigation impacts and physical modification of drainage system and embankments. Research has demonstrated that agroforestry can reduce pollution from crops and grazed pastures, with tree strips located adjacent to water courses reducing non-point source water pollution from agricultural land in five key ways [26].

1.Reducing surface runoff from fields.
2. Filtering surface runoff.
3. Filtering groundwater runoff.
4. Reducing bank erosion.
5. Filtering stream water.

The value of agroforestry systems in semi-arid regions where water availability limits agricultural sustainability demonstrates the potential role of agroforestry in temperate regions with a changing climate. In semi-arid climates, soil water content under tree canopies can be higher than in open pasture due to reduced evapotranspiration in the tree shade outweighing water uptake by plants [11, 3].

Reducing pollution

Buffer strips can significantly decrease pollution run-off, with reductions of 70-90% reported for suspended solids, 60-98% for phosphorus and 70-95% for nitrogen [5]. A study in central Iowa, US, found that a switch-grass/woody buffer removed 97% of the sediment, 94% of the total N, 85% of the nitrate-N, 91% of the total P and 80% of the phosphate P in the runoff [14]. Agroforestry systems also have the potential to mitigate movement of harmful bacteria such as Escherichia coli into water sources [9] and reduce the transport of veterinary antibiotics from manure-treated agro-ecosystems to surface water resources [6].

Reducing runoff

By reducing surface runoff and increasing infiltration and soil water holding capacity, the risk of flash flooding following periods of heavy rainfall is reduced in agroforestry systems, with the tree roots and trunks acting as permeable barriers to reduce sediment and debris loading into rivers following floods. A principal cause of non-point source pollution and soil erosion is excessive surface water runoff. Agroforestry reduced surface water runoff by 9% after just 2 years of establishment, compared with a control watershed [26]. Agroforestry can reduce soil water content during critical times such as fallow periods and increase water infiltration and water storage. Furthermore, aboveground, stems, leaf litter and pruning debris in agroforestry systems can reduce runoff flow rates, thereby enhancing sedimentation within the agroforestry strip and increasing infiltration [23].

Climate change

Carbon substitution through increased conversion of forest biomass into durable wood products to replace energy-intensive materials, increased use of biofuels and enhanced use of harvesting waste as feedstock for biofuel [17]. Agroforestry can increase the amount of carbon sequestered compared to monocultures of crops or pasture due to the incorporation of trees and shrubs [12]. Average carbon storage by agroforestry systems is estimated at 9, 21, 50 and 63 Mg C ha-1 in semiarid, subhumid, humid and temperate regions respectively, with higher rates in temperate regions reflecting longer rotations and longer-term storage [22]. The estimated contribution of agroforestry to global carbon sequestration is 1.9 Pg of carbon over 50 years, based on a worldwide estimate of 1023 million ha of agroforestry [19]. At a global scale, agroforestry systems could be established on 585 to 1274 x 106 ha of suitable land, thus storing 12 to 228 Mg C ha-1 [7]. Converting unproductive croplands and grasslands to agroforestry, an estimated 630 million ha, could potentially sequester 391,000 Mg C yr-1 by 2010 and 586,000 Mg C yr-1 by 2040 [27].

CONCLUSION

Despite concerted efforts and development in the study area, the actual adoption of agroforestry land use by the farmers was not satisfactory. The results shows that there is a need to create water resource by natural resource management with farmers confidence to availability sufficient amount of water and encourage the farmers to adopt agroforestry on their own, educate them properly through exposure visits and initially support few of the farmers who take lead by providing incentives in terms of quality planting material, improved crop seeds and fertilizers. It would be desirable to extend to agroforestry all the benefits applicable to agriculture, so that farmers can be encouraged to cultivate trees on their private lands including wastelands with equivalent benefits like price support, unrestricted movement of such produce, long term credit support on priority basis, and so on. We have to keep a knowledge that how agroforestry is maintain livelihood sustaining and strengthening system.

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