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Dynamics of Water Productivity under Agriculture and Agroforestry Land Use System in Jabalpur, Madhya Pradesh, India

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A B S T R A C T

The present study was carried out to determine the dynamics of water productivity under agriculture and agroforestry land use system in Jabalpur region of Madhya Pradesh. The statistical analysis was carried out in spilt plot design, there were two treatments and three sub treatments were taken. The main treatment was farming practices that was agroforestry and agriculture where sub treatment was different date of showing. All the product of agroforestry and agriculture were converted in to turmeric equivalent yield, total turmeric equivalent yield and Turmeric Equivalent Water Productivity (TEWP). All of these yields were used to determine water productivity. The water productivity of agroforestry was (321 kg ha^{-1}cm^{-1}) while in agriculture it was 90 kg ha^{-1}cm^{-1}

Introduction

In the light of globalization, population growth and climate change, water resources management is increasingly becoming a major sustainability challenge, especially for arid and semi-arid regions. It is widely acknowledged that water scarcity or insecurity is not only subject to physical factors and constraints, but also due to poor management of available water resources (*Molden et al.*, 2007). Water consumption has increased fourfold in the last 100 years. Population facing water scarcity increased from 0.24 billion people (14 percent of the global population 100 years ago) to 3.8 billion (58 percent of today's population) (Kummu *et al.*, 2016). Most population growth is taking place in developing countries, where water is scarce and characterized by rainfall variability, intermittent dry spells, recurrent drought years and high evaporative demand (Rockstrom *et al.*, 2007). Population share of India in world accounts as 17%, whereas fresh water share is only 4% of the total water resources across the globe. Total eradication of hunger in India requires around 1,860 km^3/yr of water by 2030 and more than 2,000 km^3/yr by 2050.

Respective increases is 160 & 180 percent compared to the current consumption of water. (*SEI*, 2005). Unlike water use in the domestic and industrial sectors, there is significant lack of information in most countries regarding agricultural water use, as irrigation abstractions from rivers, dams and aquifers (i.e. blue water), are rarely fully metered and charged (*Easter and Liu*, 2005). The economic value of water in agriculture is much lower than that in other sectors (*Barker et al.,* 2003). Many researcher across the globe found that, in developing countries, large amount of water applied to crop field for increasing the agriculture production, is lost as non-productive evaporation (Rockstrom *et al.*, 2007). According to FAO Agriculture is the main user of the water; 88 percent of all the water withdrawn is used for irrigation (FAO, 2017). Together, the increasing food demand and decreasing water allocation suggest that the agriculture sector has to produce more food with less water (*Cai and Sharma* 2010).

However, the conventional methods of cropping and badly managed resources are not able to fulfill it. There is need of certain measures/technology like water productivity which aimed at reducing water losses systems (FAO, 2012). Definition of water productivity is scale dependent. It can be analyzed at the plant level, field level, farm level, system level and basin level, and its value would change with the changing scale of analysis (*Molden et al.,* 2003). Its unit is kg m^{-3}or kg ha^{-1} cm^{-1} (1kg m^{-3}=100 kg ha^{-1} cm^{-1}). Land use system like agroforestry offers promising option for efficient and sustainable use of land and water. Water conservation and more productive use of water is one of the key benefits of agroforestry. Determination of water productivity is much common in agriculture, but it is rare in agroforestry, with special reference to India. Keeping the above facts in view, the present study was carried out analyze the dynamics of water productivity in Agriculture and Agroforestry system of crop cultivation.

Materials and Methods

The details of material used and the methods adopted during the course of study Dynamics of water productivity under agriculture and agroforestry land use system in Jabalpur, Madhya Pradesh, India

Study area

The field experiment was conducted at Dusty Acre Research Farm, Department of Forestry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The present investigation was carried out during 2014-2015.

Location and extent

Study area lies at 23^{o}12’50” North latitude & 79^{o}57’56” East longitude. Study area belongs to Kymore Plateau and Satpura Hills Agro-climatic Zone as per classification of National Agricultural Research Project. Recently, this area has been classified as agro-ecological sub-region number 10.1 (Vindhyan Scarplands, Bundelkhand, and Narmada Valley, hot dry sub-humid ecological sub region with medium deep black soil).

Topography

The topography of the area plain to gently sloping. Slope of the land vary from 0 to 1%.

Climate

Study area enjoys a typical subtropical climate with hot dry summer and cool dry winter. Temperature extremes vary between minimum temperature of 2^{0}c in December-January months to maximum temperature of 46^{0}c in May–June months. Based on 20 years mean meteorological data, the average annual rainfall of the locality is 1350 mm, which mostly received between mid-June to end of September with an occasional winter showers during December and January months. The mean monthly minimum temperature varies between 5.3 to 6.1in December and January, and maximum temperature varies between 40 to 42°C during May and June, respectively January is the coldest month of the year with minimum temperature being 5°C. Generally relative humidity remains very low during summer (20 to 23%); moderate (60 to 75%) during winter and it attains high value (80 to 95%) during rainy season.

Weather conditions during the crop season

Seasonal variations prevailing during the growth period play an important role on the growth and development of turmeric crop as well as *Dalbergia sissoo* trees, which ultimately influenced the final yield of crops. The weekly meteorological data during the course of investigation recorded at Meteorological Observatory, Agricultural Engineering College, JNKVV, Jabalpur are presented in Table 1.

It is evident from the data that weather condition was almost favourable for the growth and development of turmeric as well as shisham tree. The monsoon was commenced in the third week of June and terminated in the last week of September (Table 1). During the growing season (June 2014 to April 2015) maximum temperature (39.8) was recorded in the month of June and minimum (20.5) in the month of January. The average relative humidity was 44 to 96% in the morning and 17 to 88% in the evening. The rainfall during the crop season was 1460.8 mm and was received in 71 rainy days which had a beneficial effect on growth and development of turmeric crop as well as for the Shisham tree.

Soil

As earlier mentioned the present investigation was the third consecutive year of experimentation at the same site.

Hence, data pertaining to initial soil status of various physical-chemical properties were recorded from the soil sample taken at the time of turmeric planting from 10 places up to a depth of 0-30 cm with the help of screw type soil auger.

The soil samples were well mixed together for making representative samples. The composite samples were analyzed for physico-chemical properties of the soil in the laboratory, Department of Soil Science and Agricultural Chemistry as per standard methods.

The analytical values are presented in Table 2. To know the changes in chemical properties of the soil after three year of experimentation, soil samples from each plot were also taken and analyzed separately

Physico-chemical properties of the soil of the experimental field

It is obvious from the results that the soil of the experimental field was sandy clay loamy in texture, neutral in reaction (pH 7.21) with medium organic carbon content and having low electrical conductivity and medium in available nitrogen (N) and phosphorus (P) and low in available potash (K) content.

Experimental details

To determine the water productivity of crop + Tree (Agroforestry)

Main treatment: 2

Agroforestry
Silviculture

Sub treatment: 4

To compare the water productivity of Agroforestry and Agriculture

Main treatment: 2

Agroforestry
Agriculture

Sub treatment: 3

Observations recorded

Meteorological parameters

Daily Rainfall data
Daily Pan-evaporation

Soil physical parameters

Soil texture

Tree growth parameters

Diameter at breast height

Crop parameters

Rhizome yield

Methodology to determine crop water productivity

The crop water productivity was worked out by dividing the Turmeric equivalent yield by total water used.

Physical water Productivity (kg ha-1 cm-1) = (Total yield (kg ha-1)/Total water used (cm))

Total yield

In case of agriculture, the total output will be rhizome yield

In case of agroforestry, the total output will be rhizome, large-sized timber, small-sized timber and fuel wood.

Note

All output other than rhizome was converted into turmeric equivalent yield considering market rates of produce. The market price of different derived output under different practices was as follows:

Rhizome = Rs 55 kg^{-1}

Large-sized timber (diameter above 10 cm) = Rs 17600 m^{-3}

Small-sized timber (diameter 10cm to 7 cm) =Rs 10600 m^{-3}
Fuel wood = Rs 5 kg^{-1}

Water used

It includes the effective rainfall plus irrigation for agroforestry and agriculture and only rainfall for silviculture.

Effective rainfall

By considering daily rainfall data, mean monthly pan-evaporation, soil properties the effective rainfall has been derived from Potential Evapotranspiration /Precipitation Ratio Method (India) (FAO, 1974)

Irrigation

Water is supplied to all portions of field by pipe irrigation method. Irrigation water was calculated using pump discharge rate, time of irrigation and number of irrigation to a particular crop. The discharge rate was measured with a 40 liter drum and stop watch. This measurement was taken 3 times in a field and its means was considered for the calculation purpose.

IR (Irrigation water) = Pump discharge rate x time of irrigation x No. of Irrigation

The depth of irrigation was calculated by dividing the amount of irrigation with plot area.

Observations recorded

Daily rainfall data

The daily rainfall data during the course of investigation recorded during crop season at Meteorological observatory, College of Agricultural Engineering, JNKVV, Jabalpur.

Daily pan-evaporation data

Daily pan-evaporation data was recorded at Meteorological observatory, College of Agricultural Engineering, JNKVV, Jabalpur.

Diameter measurement of *D. sissoo*

Diameter of trees was measured with the help of calliper. Two diameter for each tree were taken perpendicularly and average was taken out as mean diameter.

Rhizome yield (Kg ha^{-1})

After harvesting and cleaning the rhizome from each net plot, it was weighed on a double pan balance. The rhizome yield per hectare was obtained by multiplying the net plot yield by the converting factor {10,000 dividing by net area (m^2) of plot}. The yield was expressed in kilograms per hectare.

Volume of large-sized (diameter above 10 cm), small-sized timber (diameter 10cm to 7 cm) and weight of fuelwood (diameter 7 cm to 4 cm)

The volume of timber and weight of fuel wood under different pruning intensities were calculated using the derived local volume table of Jabalpur region. The different regression models used were as follow;

For large-sized timber estimation Pruning intensities

$\sqrt{v} = 0.056448 + 0.01583D\ P_0$
$\sqrt{v} = -\ 0.26159 + 0.03088D\ P_{25}$
$\sqrt{v} = -\ 0.121356 + 0.02594D\ P_{50}$
$\sqrt{v} = -\ 0.14682 + 0.02878D\ P_{75}$

For small-timber estimation

$\sqrt{v} = 0.02815 + 0.00594D\ P_0$
$\sqrt{v} = -\ 0.06572 + 0.00919D\ P_{25}$
$\sqrt{v} = -\ 0.01037 + 0.00684D\ P_{50}$
$\sqrt{v} = -\ 0.14423 + 0.01367D\ P_{75}$

For fuel-wood estimation

$\sqrt{w} = 2.84865 + 0.11694D\ P_0$
$\sqrt{w} = -\ 1.84900 + 0.31852D\ P_{25}$
$\sqrt{w} = -\ 0.24751 + 0.20303D\ P_{50}$
$\sqrt{w} = -\ 1.36957 + 0.24582D\ P_{75}$

Where,

v = Volume (m^3)
w= Weight (kg)
D = Diameter at breast height (cm)

Statistical analysis

The data calculated from the experiment were tabulated and analyzed statistically by method of analysis of variance as suggested by Cochran and Cox (1950).

The significance of the treatment mean square at 5 percent level was tested with 'F' test.

When 'F' test showed the significance of treatment using the significance of critical differences at 5 per cent level further tested the differences between the treatment means.

Table.1 Weekly meteorological parameters during the crop season (June2014 to March 2015)

Month	Meteo. Week	Temperature		Relative Humidity%		Sun-Shine hrs	Rainfall (mm)	No of Rainy days	Wind vel. (Km/hr)
		Max.	Min.	Morning	Evening				
June	**24**	39.8	26.4	64	37	6.2	37	3	7
	25	35.6	25.6	74	52	7	72.6	4	7.9
	26	36.5	26.4	65	38	4.5	9.8	1	6.5
July	**27**	34.5	26.1	71	41	6.5	296.8	3	7.4
	28	31.3	25.6	79	59	5.9	116	4	7.1
	29	32.3	24.5	90	79	3.2	117.5	6	5.8
	30	28.2	23.3	91	79	3.4	119.9	3	5.5
Aug.	**31**	26.3	24.6	92	79	2.3	32.4	5	5.4
	32	27.7	23.7	86	73	4.9	145.8	5	7.9
	33	28.2	24	86	63	5	101.8	2	6.1
	34	30.2	25.1	83	58	6.7	84.4	0	3.1
	35	31.9	24.2	88	65	7.8	3	2	4.1
Sept.	**36**	30.8	23.7	91	71	2.4	52.2	7	4.1
	37	30.7	23.4	91	72	3.8	87.4	6	4.8
	38	30.8	23.5	89	55	8.5	11	1	4.2
	39	31.9	21.6	85	41	10	0	0	2.5
Oct.	**40**	33.4	21	86	53	9.4	2.3	1	2.3
	41	32.4	20.4	88	55	8.4	0	2	4.7
	42	32.5	18.8	91	44	7.9	0	0	2.3
	43	31.6	16.6	89	41	8.8	0	0	1.7
	44	27.9	14.4	87	29	8.6	0	0	1.6
Nov.	**45**	28.2	13.9	87	29	8.2	0	0	2.6
	46	28.6	14.4	83	26	6	0	0	2.5
	47	27.9	8.9	82	20	8.6	0	0	1.8
	48	28.4	10.2	85	24	8.6	0	0	2.1
Dec.	**49**	28.7	8	88	24	8.7	0	0	2.5
	50	29	11.8	89	52	6.2	3.2	1	2.6
	51	25.3	5.6	86	32	7.6	0	0	2.2
	52	23.8	4.8	87	32	8.5	0	0	2.1
Jan.	**1**	20.5	11.7	90	61	6.5	37.7	3	3.8
	2	22.1	5.3	87	38	8.5	0	0	2.1
	3	22.2	5.3	91	37	8.3	0	0	2.6
	4	21.6	12.1	89	75	3.7	10.2	2	3.3
	5	22.5	8.7	85	44	9.8	10.8	2	2.7
Feb.	**6**	24.2	10.2	88	52	7.1	14.4	1	4.5
	7	26.8	10.4	88	40	9.1	6.2	1	2.8
	8	30.6	12	86	33	9.7	0	0	1.9
	9	26.7	14.5	85	54	6.8	64.8	3	3.2
March	**10**	28	12	85	39	9.5	0	0	2.9
	11	26.8	15.2	87	54	6..0	23.6	3	3.6
	12	31.8	13.8	80	26	10.3	0	0	2.2
	13	35.4	19	55	23	9.5	0	0	5.3

Table.2 To compare the water productivity of Agroforestry and Agriculture

Source of variation	d. f	S.S	M.S.S	F cal	F tab	
					at 5%	at 1%
Replication	3					
Main treatment (Farming Practice)	1				10.13	34.12
Error A	3					
Sub-treatment (Date of sowing)	2				3.88	6.93
Interaction	2				3.88	6.93
Error B	12					
Total	23					

Skeleton for analysis of variance (ANOVA)

Table.3 Turmeric yield of agroforestry and agriculture (kg ha^{-1})

Practices	Average
Agroforestry	2926
Agriculture	6170
SEm±	1540
CD at 5%	4900
CD at 1%	8996

Table.4 Turmeric yield in different date of sowing (kg ha^{-1})

Date of sowing	Yield
D1	4805
D2	4377
D3	4463
SEm±	514
CD at 5%	1120
CD at 1%	1571

Table.5 Turmeric equivalent yield of agroforestry and agriculture (kg ha^{-1})

Practices	Yield
Agroforestry	21985
agriculture	6170
SEm±	2152
CD at 5%	6847
CD at 1%	12568

Table.6 Total TEY in different date of sowing (kg ha^{-1})

Date of sowing	Yield
D1 (20-06-2014)	15938
D2 (27-06-2014)	13149
D3 (05-07-2014)	13145
SEm±	892
CD at 5%	1943
CD at 1%	2725

Table.7 Turmeric equivalent water productivity (TEWP) of agroforestry and Agriculture (kg ha^{-1} cm^{-1})

Practices	TEWP (kg ha^{-1} cm^{-1})
Agroforestry	321
Agriculture	90
SEm±	31
CD at 5%	100
CD at 1%	183

Table.8 Turmeric equivalent water productivity in different date of sowing (kg ha^{-1} cm^{-1})

Date of sowing	TEWP (kg ha^{-1} cm^{-1})
D1	233
D2	192
D3	192
SEm±	13
CD at 5%	28
CD at 1%	40

Results and Discussion

The findings of present study were analyzed and found the following details as follow Three sowing dates for turmeric were viz., 20-6-2014 (D1), 27-6-2014 (D2) and 05-07-2014 (D3).

TEWP of these three sowing date are evaluated. The output of agroforestry is turmeric LST, SST and FW whereas output of agriculture is turmeric only. The LST, SST and FW were converted in to TEY in agroforestry

Turmeric yield of agroforestry and agriculture

As shown in Table 3. The mean yield of agroforestry is 2926 kg ha^{-1}, whereas it is 6170 kg ha^{-1} in Agriculture system

As shown in Table 4 the turmeric yield in different dates of sowing are at par with each other.

Turmeric yield in D1 (4805 kg ha^{-1}), D2 (4377 kg ha^{-1}) and D3 (4463 kg ha^{-1}) were recorded.

Total Turmeric equivalent yields in agroforestry and agriculture

All products of agroforestry viz., LST, SST, FW and turmeric yield were converted in to TEY and added to get total TEY of agroforestry. It was analysed with TEY of agriculture. Total turmeric equivalent yield of agroforestry (21985 kg ha^{-1}) was significantly superior to agriculture (6170 kg ha^{-1}) (Table 3).

As shown in Table 4 Total TEY in D1 (15938 kg ha^{-1}) is significantly superior to, D2 (13149 kg ha^{-1}) and D3 (13145 kg ha^{-1}). D2 and D3 are at par.

These total turmeric equivalent yield (TEY) were considered for determining the water productivity of different treatments.

Water productivity in agroforestry and agriculture (kg ha^{-1} cm^{-1})

To determine the turmeric equivalent water productivity (TEWP), total TEY of different treatment were divided by the water used in respective treatments. Water used in agroforestry treatment and agriculture treatment was 68.5cm.TEWP of agroforestry (321 kg ha^{-1} cm^{-1}) was significantly superior with the agriculture (90 kg ha^{-1} cm^{-1}). Table 7.

The TEWP of D1 (233kg ha^{-1} cm^{-1}) was significantly superior to D2 (192kg ha^{-1} cm^{-1}) and D3 (192kg ha^{-1} cm^{-1}). Table 8

TEWP of different farming practices

As per Table 7 reveals that TEWP of agroforestry (321kg ha^{-1} cm^{-1}) is significantly superior than TEWP of agriculture (90kg ha^{-1} cm^{-1}). It is clear from that significantly lower TEWP was recorded in agriculture (90kg ha^{-1} cm^{-1}) and the TEWP of agroforestry was (321kg ha^{-1} cm^{-1})

In view of turmeric equivalent water productivity TEWP, agriculture farming practice (90 kg $ha^{-1}cm^{-1}$) as inferior among selected farming practices though agriculture utilized the same quantity of water (68.5 cm) like agroforestry, but yielded only 90 kg $ha^{-1}cm^{-1}$ TEWP, whereas agroforestry have 321 kg $ha^{-1}cm^{-1}$ TEWP. If the Moto of farming is "more biomass per drop of water" then agriculture farming fails in achieving this Moto. The agroforestry (321 kg $ha^{-1}cm^{-1}$) can choose best farming practice on the basis of water availability and demand of biomass. If sufficient water is available then go for agroforestry practice which gives more biomass and compare to agriculture.

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