Original Research Article

A Study on Irrigation Water Productivity Under Different Irrigation Environments of Tamil Nadu

ABSTRACT

The world is attempting to increase water efficiency in all activities especially in irrigation which consumes three-fourth of total available water. In concern to the near future food demand and sustainability issues, views are directed to reduce the usage or increase the efficiency of water. India is a major contributor of agricultural production and feeder to many countries. Irrigated agriculture is being followed by the many farmers in India which consumes huge amounts of water. Considering the monsoon failure, increasing the water demand, one has to find the possibilities to retain the water in an available manner. In this way, a problem is focused that to find major water-consuming crops and irrigation methods in different irrigation environments of Tamil Nadu. Pudukottai, Salem and Erode are the districts of Tamil Nadu state selected as a study area. In each district, blocks, villages and respondents are selected through multi-stage random sampling. This study is entirely based on primary data which is collected using a well-structured interview schedule. The collected data is used to estimate the Physical Water Productivity (PWP) and Economic Water Productivity (EWP). The results show that PWP and EWP are vary across crops under different irrigation environments. In a tank environment, the alternate drying and wetting method of irrigation in paddy is effective and saves around 39 per cent of water compared to the conventional method of flood method. For Groundnut crops, drip irrigation is more effective than check basins which are better than the flood method of irrigation. We can conclude that the farmers should follow water-saving irrigation methods/technologies and cultivate less water demand/consumption crops in water scarcity season and can cultivate the water consuming crops like sugarcane and banana in water surplus season.

Keywords: Irrigated agriculture, Irrigation methods, Physical Water Productivity (PWP), Economic Water Productivity (EWP).

1. INTRODUCTION

Water, a renewable natural resource is getting limited in India due to intense consumption among water-dependent sectors. Agriculture is not an exemption that consumes the majority of water for irrigating the crops alone. Being an agrarian country, the overall consumption of water for agriculture is extremely high among the water-consuming sectors. Failure of or delayed monsoons, cultivation of high-water requirement crops in water deficit regions and rising temperatures ways to increase crop water demand are some of the major causes for prevailing water problems in India and the agriculture sector. Irrigated agriculture, the major contributor to agricultural production, poses the issue of optimizing irrigation water usage efficiency and simultaneously ensuring food security (Kang *et al.*, 2017, Zwart and Bastiaanssen, 2004).

Irrigation is the most important element impacting agricultural productivity in the dry sub-humid and arid regions (Oweis & Hachum, 2003). Irrigation water productivity (IWP), defined as the yield produced per unit of irrigation water use (Molden, 1997), has become an essential criterion that considers both agricultural output and water use efficiency. It is a comprehensive indicator that indicates the degree of irrigation and crop management (Seckler *et al.,* 2004, Abdullaev and Molden, 2004, Zoebl, 2006). Raising the value of IWP would not only relieve the strain on scarce water resources but would also secure food security (Ali & Talukder, 2008, Molden, 1997). Understanding the effects of driving variables on IWP aids in the exploration of strategies to improve IWP, which is important for effective water use and agricultural sustainability development.

Food demand will increase significantly as the population grows. At the same time, water demand from non-agricultural sectors will continue to rise in both developed and developing countries. According to a recent FAO research (Bruinsma, 2017) of 93 developing countries, agricultural production would rise by 49 per cent in rainfed systems and 81 per cent in irrigated systems between 1998 and 2030. As a result, a large portion of the extra food production is predicted to come from irrigated land, three-quarters of which is in developing nations. The International Food Policy Research Institute (IFPRI) recently conducted research on water productivity that used somewhat different assumptions than FAO (Cai and Rosegrant, 2003). According to this analysis, the average water productivity of rice would grow from 0.39 to 0.53 kg per m^3 in developing countries and from 0.47 to 0.57 kg per m^3 in developed countries between 1995 and 2025. According to IFPRI, the average water productivity of all other cereals would improve from 0.56 to 0.94 kg per m^3 in poor countries and from 1.00 to 1.32 kg per m^3 in rich nations during the same time. As a result, meeting the expected water productivity needed to feed the world's rising population will be a challenge for breeders, agronomists, and irrigation professionals in the future years.

This paper aims to discuss the irrigation (both physical and economic) water productivity in different irrigation environments such as canals, tanks and wells in Tamil Nadu. Different technologies or various methods are being followed by the farmers for irrigating the crops. So, the water productivity is analyzed under different methods of irrigation in three irrigation environments.

2. LITERATURE REVIEW

Arun S. Patel (1981) notes the extent to which irrigation and new technology have expanded in his work titled "Irrigation: Its Employment Impact in the Command Areas of Medium Irrigation Projects in Gujarat." This expansion has also contributed to raising the standard of life and launching an employment opportunity drive that is falling short of the desired level of productivity. Irrigation has resulted in significant alterations in farming patterns. Specifically, I a shift from inferior cereals and pulses to superior cereals, (ii) a shift from food grains to non-food grains (both long and short-duration crops), (iii) a shift from crops if Indigenous (Desi) varieties to HYVs in both food grain and non-food grain crops, and (iv) a shift from food grain to non-food grain crops.

Himanshu Takkar (1999) finds in his research that irrigation is becoming increasingly important in agriculture. The globe has seen this over the last two decades, as irrigation's steady expansion began to wane between 1979 and 1982. Between 1982 and 1994, the global irrigated area grew at an annual rate of 13%, down from an annual rate of 2%. Even if the prediction is correct, the worldwide irrigation base is unlikely to grow faster than 0.6% per year for the next 25 years. Since 1980, per capita irrigated acreage has decreased, resulting in stagnation in per capita grain production and bringing a new dimension to global food security.

Irrigation is the most significant input required for agricultural development in India, according to Lekhi R. K. (2004). He discovers that irrigation allows for multiple cropping and boosts crop output, making it useful in agriculture. This goal can only be met by supplying growers with reliable irrigation infrastructure. Even after the recent implementation of nine five-year plans, Indian agriculture remains a monsoon gamble. People have experienced a drought in many regions of the country as a result of difficulties such as monsoon failure for nearly two years in a row. It also caused famine or near-famine conditions in several locations. It is considered that irrigation systems can free farmers from complete reliance on nature while maintaining their faith in them.

Food and Agricultural Organization (2003) defines the term water productivity as the amount or value of a product over the volume or value of water depleted by the plant, of which the value of the product might be expressed in different terms (biomass, grain, money).

WP is most commonly measured as crop output per cubic metre of water. Partial water productivity can be expressed in physical or economic terms as follows (Seckler *et al.,*):

1. Pure physical productivity is defined as the quantity of the product divided by the quantity of the input. Examples include crop yield per hectare or cubic metre of water either diverted or consumed by the plant. For example, the International Water Management Institute (IWMI) sees as one of its primary objectives 'increasing the crop per drop'.

2. Productivity, combining both physical and economic properties, can be defined in terms of either the gross or the net present value of the product divided by the amount of water diverted or consumed by the plant.

3. Economic productivity is the gross or net present value of the product divided by the value of the water either diverted or consumed by the plant, which can be defined in terms of the value or opportunity cost in the highest alternative use.

Hussain *et al.,* (2005) point out that the most meaningful measure is of marginal value, that is, the additional value that is created when water is added (or lost when water is not available). WP assessment is more directly linked to problems in water-scarce or water-costly situations than in systems that are supplied with plentiful, low-value water. WP is most meaningful as an indicator as water resources become increasingly scarce

Molden *et.al.,* (2007) defined water productivity as the ratio of the net benefits from the crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce those benefits. In its broadest sense, it reflects the objectives of producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of water used, where water use means either water delivered to use or depleted by use. Put simply, it means growing more food or gaining more benefits with less water. Physical water productivity is defined as the ratio of the mass of agricultural output to the amount of water used, and economic productivity is defined as the value derived per unit of water used. Water productivity is also sometimes measured specifically for crops (crop water productivity) and livestock (livestock water productivity).

3. METHODOLOGY

For each irrigation environment, three districts were purposively selected such as Pudukottai, Salem and Erode. The details of districts and blocks selected for study are shown in Figure.1. As of 2020-21 data, Pudukottai district is named for tank irrigation consisting of 5451 tanks which is the highest compared to other districts in Tamil Nadu. Salem district is selected for well irrigation environment which has the highest number of irrigation wells of 108745. Erode district is selected for canal irrigation which covers 690 km length of canal length. Multi-stage sampling technique is followed for the selection of blocks, villages and respondents in each irrigation environment.

3.1 Cost and Returns Analysis

The different items of variable costs such as labour cost, seed cost, fertilizer cost, plant protection cost, and irrigation cost; and fixed cost items viz., rental value land, land revenue, and interest and depreciation on farm buildings and implements were worked out as per the methodology defined by Government of India (1990) to analyze the profitability of rice production.

3.2 Physical and Economic Water Productivity

The water flow is measured using the float method in each respondent's farm and the water flow rate is collected. The other data for such operational expenses, fixed expenses and yield are collected from respondents through a well-structured interview schedule. A total of 360 respondents are interviewed for my research purpose. Based on the primary data collected, analysis of Physical and Economic Water Productivity are worked out using the following methodology:

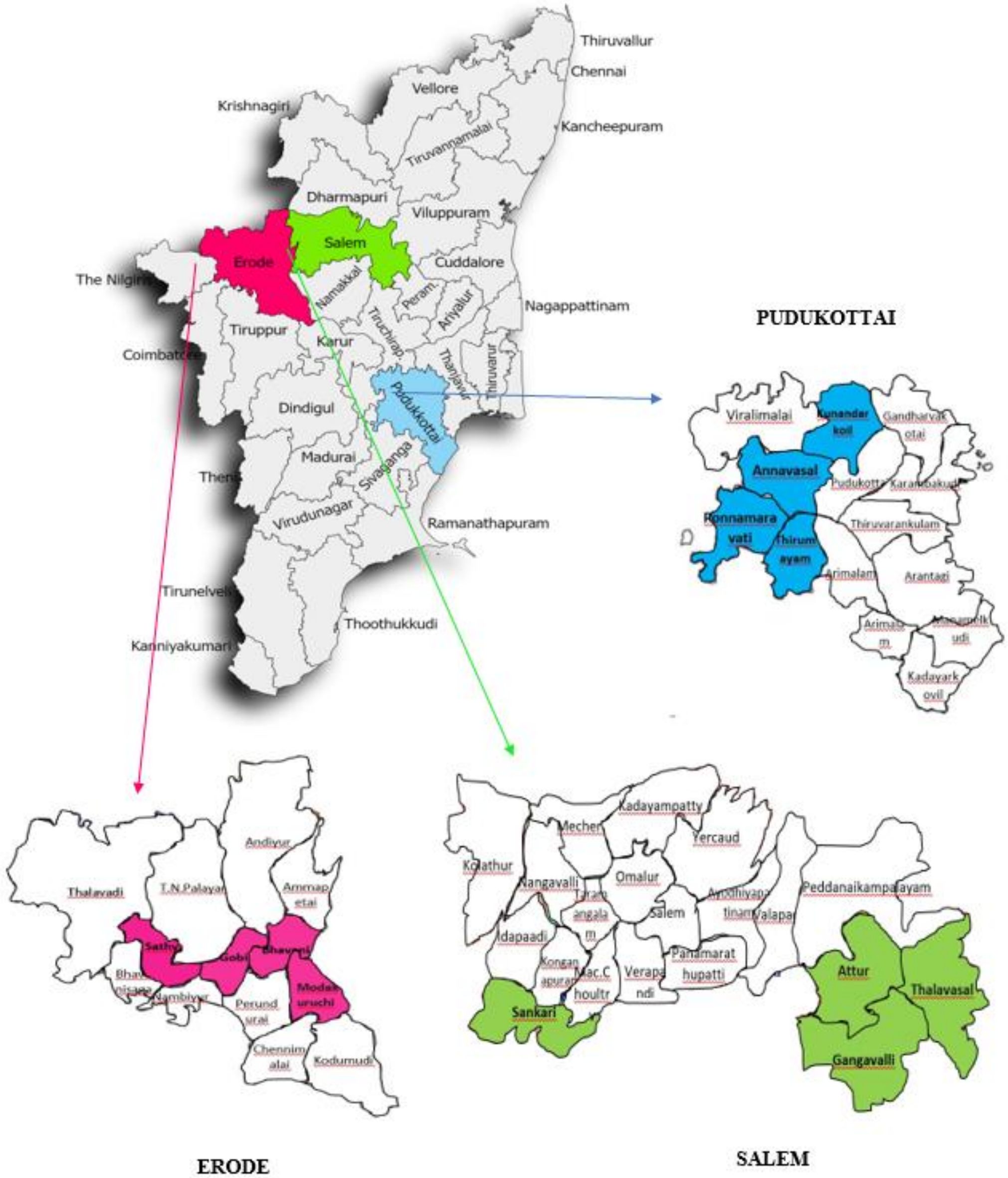
The physical water productivity PWP (kg/m^3) and water productivity in economic terms, EWP (Rs. /m^3) in a purely irrigated crop are estimated as:

$$\mathrm{PWP}(\mathrm{kg/m^3}) = \frac{\partial\ (\mathrm{kg/ha})}{\Delta\ (\mathrm{m^3/ha})}$$

$$\mathrm{EWP}(\mathrm{Rs./m^3}) = \frac{\mathrm{NR}\ (\mathrm{Rs./ha})}{\Delta\ (\mathrm{m^3/ha})}$$

Δ and ∂ are the irrigation water used (m^3/ha) and yield of the crop (Kg/ha.) for purely irrigated crops. NR is the net return per unit area of the crop (Rs. /ha.). Cost and returns are worked out for each crop to derive the NR. All crops selected for the study are purely irrigated crops, and the green water used for the crop is not considered. The water flow rate is measured using the float method which is measuring small to large water flow with medium accuracy and this method is best used in streams with calm water and during periods of good weather for if there is too much wind and the surface of the water is rough the float may not travel at the normal speed. The crops considered are sugarcane and turmeric in a canal irrigation environment, sorghum and groundnut in a well irrigation environment and paddy and groundnut in a tank irrigation environment were treated as irrigated crops, and therefore the water productivity estimated for them is irrigation water productivity.

Figure 1: Selected Districts and Blocks In Tamil Nadu



4. RESULTS AND DISCUSSION

The concept of PWP is important as irrigation is what it costs to make the water available for use in agriculture. Hence, PWP, considering the crop output produced per unit of irrigation water applied in the field gives a more accurate picture from an economic point of view, especially for water-intensive crops like paddy and sugarcane. Thus, PWP and EWP are worked out for three major crops in the tank irrigation environment – paddy, groundnut and black gram, which occupy about 47 per cent of the gross cropped area in Tamil Nadu. The cost and returns of crops in different irrigation environments are given in Table 1. The estimated PWP and EWP of major crops in a tank irrigation environment was provided in Table 1.

Table 1: Cost and Returns of Crops in Different Irrigation Environments

Irrigation Environment	Crops	Fixed Cost (Rs. /ha)	Variable Cost (Rs. /ha)	Gross Returns (Rs. /ha)	Net Returns (Rs. /ha)
Canal	Paddy	11577	50540	92708	30591
	Turmeric	11900	177558	361429	171971
	Sugarcane	27013	69444	131250	34793
	Banana	18347.38	113279.81	234000	102372
Well	Maize	9028.92	59179	127490	59282
	Tapioca	13393	107686	268736	147657
	Sorghum	10328.50	19479.89	87120	57311
Tank	Paddy	10888.05	53064.37	86480	22527
	Groundnut	22147.25	79617.98	118905.8	17140
	Black gram	16955.26	46817.61	77805	14032

Source: Author's estimation

The paddy farmers in a tank irrigation environment report the highest land productivity of paddy (4.9t/ha). The PWP is also high to the tune of 0.40 kg/m^3 respectively whereas the EWP is 1.61 Rs. /m^3 in flood type irrigation method whereas in alternate wetting and drying method, the paddy farmers obtain more PWP and EWP of 0.61 kg/m^3 and 3.06 Rs. /m^3. Through the water-saving technology used by the farmers, 39 per cent of the water is saved compared to conventional methods of irrigation. The PWP and EWP of Groundnut are 0.45 kg/m^3 and 2.98 Rs. /m^3 respectively in the check basin method of irrigation whereas in flood or open type irrigation, farmers availing 0.38 kg/m^3 of PWP and 2.79 Rs. /m^3 of EWP which is lesser than the check basin type of irrigation. The PWP and EWP of Black gram are 0.50 kg/m^3 and 18.42 Rs. /m^3 respectively in the check basin method whereas in the open/flood type method of irrigation, farmers obtaining 0.33 kg/m^3 of PWP and 15.00 Rs. /m^3 of EWP. The results indicate that the farmers following open or flood-type methods of irrigation incur high water dosages and lower productivity. The reason is an uneven distribution of water throughout the field which in turn lesser nutrient uptake by the crop through water is lowered followed by a decline in the productivity of the crop. The high land productivity owing to assured irrigation, added with an effective and assured procurement policy for paddy further encourages farmers to cultivate this crop despite the rising water sustainability issues. Considering the other two crops, Black gram has the highest EWP than other crops. But overall, the net income obtained was higher in paddy. The farmers have to concentrate on pulses cultivation concerning water sustainability issues and also better technology has to be provided to farmers to increase the yield of pulses without an increase in water requirement.

Table 2 Irrigation Water Productivity of Different Crops in Tank Irrigation Environment of Tamil Nadu

(Numbers)

Name of the crop	Irrigation Methods/Technologies	Physical Water Productivity (Kg/m^3)		Water Productivity in Economic Terms (Rs. /m^3)	
		Average	Range	Average	Range
Paddy	Flood	0.40	0.08-0.94	1.61	0.32-7.55
	Alternate wetting and drying	0.61	0.21-0.78	3.06	2.89-3.26
Groundnut	Check basin	0.45	0.09-1.41	2.98	1.23-29.15
	Flood	0.38	0.26-0.45	2.79	2.62-2.89
Black gram	Check basin	0.50	0.38-0.88	18.42	13.30-23.55
	Flood	0.33	0.29-0.40	15.00	13.90-16.12

Source: Author's estimation

Irrigation Water Productivity of different crops in the well irrigation environment of Tamil Nadu is given in Table 2. The maize farmers in a well irrigation environment report the highest land productivity of maize (5.79t/ha). The PWP is also high to the tune of 1.70 kg/m^3 respectively whereas the EWP is 5.78 Rs. /m^3 in the check basin method, 2.90 PWP and 7.20 EWP in drip irrigation or micro irrigation method. Farmers obtained better results in the drip irrigation method than in the check basin method. Comparing the PWP of three major crops in a good irrigation environment, Tapioca has the highest PWP of 5.26 kg/ m^3 in the check basin method and 5.80 kg/ m^3 in the drip irrigation method whereas the PWP of sorghum is 0.26 kg/m^3, 0.40 kg/m^3, 0.23 kg/m^3 in check basin, drip and open method of irrigation respectively. EWP is high in sorghum crop which accounts that 9.03 Rs. /m^3, 11.20 Rs. /m^3 and 6.39 Rs. /m^3 in check basin, drip and open methods of irrigation, whereas the for maize crop are 5.78 Rs. /m3 in check basin method and 7.20 Rs. /m3 in drip irrigation method and for tapioca crop, are 4.96 Rs. /m^3 and 5.22 Rs. /m^3 respectively. The crop Sorghum has the lowest PWP of 0.26 kg/m^3 and the highest EWP of 9.03 Rs. /m^3 which is considered an efficient crop in terms of water sustainability issues.

Table 3 Irrigation Water Productivity of Different Crops in the Well Irrigation Environment of Tamil Nadu

(Numbers)

Name of the Crop	Irrigation Methods/Technologies	Physical Water Productivity (Kg/m^3)		Water Productivity in economic terms (Rs. $/m^3$)	
		Average	Range	Average	Range
Maize	Check basin	1.70	0.24-8.51	5.78	0.77-27.93
	Drip/Micro	2.90	2.64-3.40	7.20	3.45-14.90
Tapioca	Check Basin	5.26	1.04-30.87	4.69	0.84-32.57
	Drip/Micro	5.80	1.60-6.30	5.22	0.98-13.35
Sorghum	Check basin	0.26	0.03-0.57	9.03	-0.13-29.42
	Drip/Micro	0.40	0.21-0.69	11.20	5.40-19.25
	Open/flood	0.23	0.11-0.38	6.39	4.28-8.20

Source: Author's estimation

The PWP and EWP of major crops in the canal irrigation environment are given in Table 3. The sugarcane farmers in the canal irrigation environment report the highest land productivity of paddy. The PWP is also high to the tune of 5.16 kg/m^3 and 7.20 kg/m^3 in furrow and drip irrigation methods whereas the EWP is 1.66 Rs. $/m^3$ and 2.01 Rs. $/m^3$ in furrow type and drip irrigation method respectively. The PWP of turmeric is 0.35 kg/m^3 (furrow method) and 0.43 Rs. $/m^3$ (drip method) whereas farmers availing 9.69 Rs. $/m^3$ of EWP (Furrow method) and 13.33 Rs. $/m^3$ (Drip method) of EWP. The PWP and EWP of banana is 1.04 kg/m^3 and 3.43 Rs. $/m^3$ respectively in the open/flood irrigation method. Paddy farmers follow flood-type irrigation methods only and they are achieving 0.20 kg/m^3 of PWP and 0.98 Rs. $/m^3$ of EWP. The results indicate that the farmers following open or flood type methods of irrigation incur high water dosage and lower productivity compared to the water-saving irrigation method. The reason is an uneven distribution of water throughout the field which in turn lesser nutrient uptake by the crop through water is lowered followed by a decline in the productivity of the crop. The high land productivity owing to assured irrigation, added with an effective and assured procurement policy for paddy further encourages farmers to cultivate this crop despite the rising water sustainability issues. Considering the water scarcity issues, farmers in canal irrigation environments have to cultivate turmeric crops in water scarcity periods/regions to achieve both EWP and PWP and cultivate other crops when water availability is considered plenty.

Table 4 Irrigation Water Productivity of Different Crops in Canal Irrigation Environment of Tamil Nadu

(Numbers)

Name of the Crop	Irrigation Methods/Technologies	Physical Water Productivity (Kg/m^3)		Water Productivity in Economic Terms (Rs. /m^3)	
		Average	Range	Average	Range
Paddy	Flood	0.20	0.07-0.58	0.98	0.22-2.46
Turmeric	Furrow	0.35	0.08-0.93	9.69	0.66-29.84
	Drip	0.43	0.12-0.59	13.33	4.56-21.23
Sugarcane	Furrow	5.16	1.85-10.78	1.66	0.74-3.66
	Drip	7.20	3.25-11.23	2.01	1.00-4.65
Banana	Flood	1.04	0.37-2.63	3.43	0.7-11.20

Source: Author’s estimation

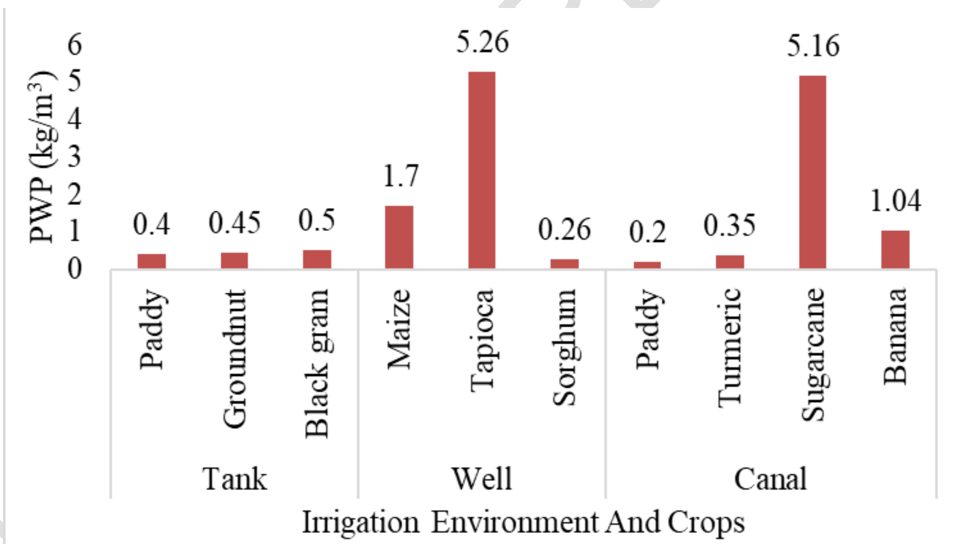


Fig .2 PWP of crops of different irrigation enviroments

The status of each crop on PWP of crops of different irrigation environments is given in Fig.2. The graph showed that the quantity produced per cubic meter of water consumed in different irrigation environments of Tamil Nadu, 0.4 kg of paddy, 0.45 of groundnut and 0.5 kg of black gram in tank irrigation environment, 1.7 kg of maize, 5.26 kg of tapioca, 0.26 kg of sorghum in well irrigation environment, 0.2 kg of paddy, 0.35 kg of turmeric, 5.16 kg of sugarcane and 1.04 kg of banana in canal irrigation environment.

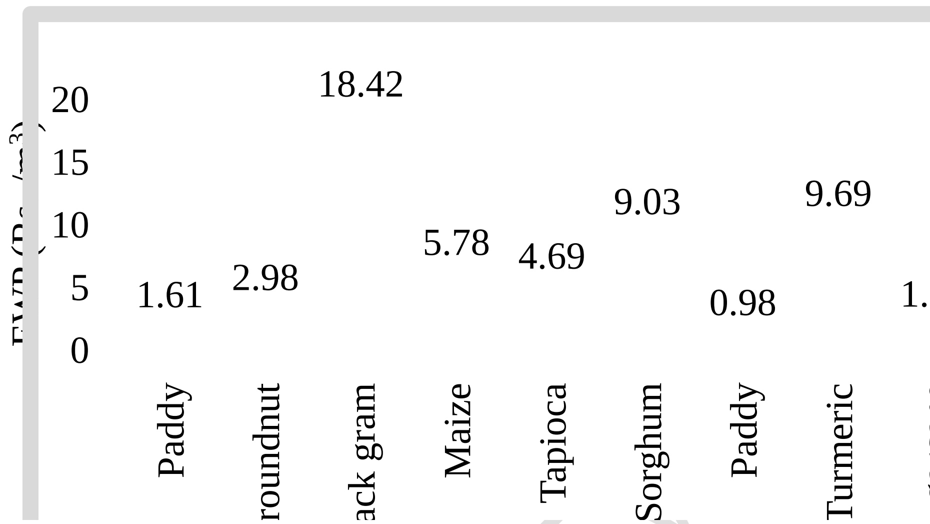


Fig .3 EWP of crops of different irrigation environments

The status of each crop on this indicator is given in Fig.3. The graph shows that the net production value per cubic meter of water consumed in different irrigation environments, Rs. 1.61 for paddy, Rs. 2.98 for groundnut and Rs. 18.42 in black gram in tank irrigation environments, Rs. 5.78 in maize, Rs. 4.69 in tapioca and Rs. 9.03 in sorghum in well irrigation environments and Rs. 0.98 in paddy, Rs. 9.69 in turmeric, Rs. 1.66 in sugarcane and Rs. 3.43 in a banana crop of canal irrigation environments.

5. CONCLUSION

To increase WP, it is required to ascertain the maximum or achievable WP that may be attained under particular circumstances as well as the actual WP, which is the baseline or existing state of WP in a given system. When recommending WP improvement methods, it is important to have a realistic understanding of the circumstance. By quantifying the WP gap, the potential for progress may be measured. It is crucial to measure the WP gap for a variety of reasons. The major steps to increase both PWP and EWP are 1. Identify the sources of the WP gaps. 2. Provide management measures to close the gaps.

REFERENCES

Abdullaev, I., & Molden, D. (2004). Spatial and temporal variability of water productivity in the Syr Darya Basin, central Asia. *Water Resources Research*, *40*(8).

Ali, M. H., & Talukder, M. S. U. (2008). Increasing water productivity in crop production—A synthesis. *Agricultural water management*, *95*(11), 1201-1213.

Bruinsma, J. (2017). *World agriculture: towards 2015/2030: an FAO perspective*. Routledge.

Cai, X. M., & Rosegrant, M. W. (2003). World water productivity: current situation and future options. *Water productivity in agriculture: limits and opportunities for improvement*, 163-178.

Kang, S., Hao, X., Du, T., Tong, L., Su, X., Lu, H., ... & Ding, R. (2017). Improving agricultural water productivity to ensure food security in China under changing environment: From research to practice. *Agricultural Water Management*, *179*, 5-17.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M. A., & Kijne, J. (2010). Improving agricultural water productivity: Between optimism and caution. *Agricultu0.ral water management*, *97*(4), 528-535.

Molden, D. (1997). *Accounting for water use and productivity* (No. 42). International Water Management Institute (IWMI).

Oweis, T. Y., & Hachum, A. Y. (2003). Improving water productivity in the dry areas of West Asia and North Africa. In *Water productivity in agriculture: Limits and opportunities for improvement* (pp. 179-198). Wallingford UK: CABI Publishing.

Seckler, D., Molden, D., & Sakthivadivel, R. (2003). The concept of efficiency in water-resources management and policy. In *Water productivity in agriculture: Limits and opportunities for improvement* (pp. 37-51). Wallingford UK: CABI Publishing.

Zoebl, D. (2006). Is water productivity a useful concept in agricultural water management?. *Agricultural Water Management*, *84*(3), 265-273.

Zwart, S. J., & Bastiaanssen, W. G. (2004). Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. *Agricultural water management*, *69*(2), 115-133.