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Original Article

Horticulture, Water Use Efficiency and Sustainable Agriculture in the Pravara River Basin

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Abstract:

Orchards have become a major part of agricultural diversification in semi-arid areas since fruits and vegetables crops have the potential to yield greater economic outcomes using comparatively minor agricultural area (Chadha, 2002). Pravara River Basin of Maharashtra offers a valid geographical location where one can study this relationship since irrigation development greatly affects agriculture in the basin, the state of groundwater, and shifting crop preferences and climatic variability (Landge & Kadam, 2016). This paper explores the history of horticulture, the relevance of water-use efficiency and the future of viable agriculture in the Pravara River Basin with the help of secondary data retrieved in the form of government texts, published articles, institutional documents, agricultural statistics and literature (Ministry of Agriculture and Farmers Welfare, 2024). Special focus will be placed on pomegranate and other horticultural crops since the Mula-Pravara region has been observing a significant transition in conventional food crops into commercial and plantation crops (Duraisamy et al., 2018).

The analysis has shown that the area of horticultural plantations has grown in 19.08 km2 in 1991 to 324.6 km2 in 2016 with a growth rate of about 1,601.4 (Duraisamy et al., 2018). Meanwhile, the growth in irrigated agriculture has strained the availability of the groundwater, especially in the semi-arid region of the basin (Central Ground Water Board, 2017). Pomegranate irrigation studies in Ahmednagar have shown that evapotranspiration of crops and crop coefficients may be employed to optimize irrigation schedules and water administration to crops (Gorantiwar et al., 2011). The researchers conclude that horticulture can bring sustainable development of agricultural activities in the Pravara Basin only in case of crop diversification, which is followed by micro-irrigation, scientific irrigation schedule, mulching, groundwater management, and better water productivity (Meshram et al., 2016).

Keywords: Horticulture, Water Use Efficiency, Sustainable Agriculture, Pravara River Basin, Pomegranate, Irrigation, Groundwater, Maharashtra, Semi-arid Region, Agricultural Sustainability.

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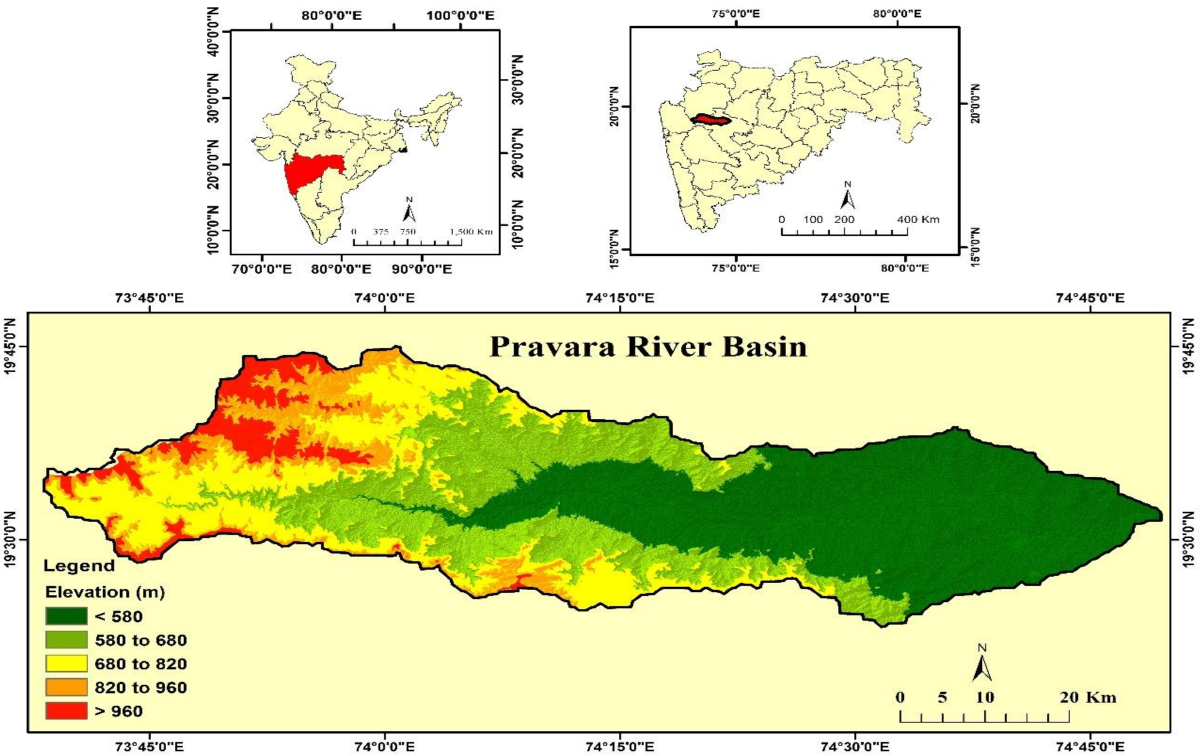
Introduction:

Water belongs to the number of the most critical natural resources, which aid in the agricultural production, especially in semi-arid areas, where the rainfall rates are low and extremely unpredictable (FAO, 2017). Such regions rely more and more on the possibility to generate more economic and biological output in each unit of available water in agricultural development (Molden et al., 2010). The concept of water-use efficiency has thus taken on a significant role of modern agricultural planning, particularly in areas where groundwater abstraction and irrigation stress is on the rise (Perry et al., 2009). The case of horticultural crops is especially pertinent since it is possible to get more valuable agricultural output and at the same time, Horticultural crops may enable the farmers to integrate more advanced irrigation methods (Sharma and Upadhyay, 2011). Maharashtra has become one of the biggest horticultural states in India, where much of the production of grapes, pomegranate, mango, banana, citrus and vegetable crops is processed (Government of Maharashtra, 2025). In the Maharashtra Economic Survey, the size of horticultural area is in the range of 21.74 lakh hectares in 202324 and the horticulture production is in the range of 326.88 lakh metric tonnes (Government of Maharashtra, 2025). The Pomegranate has a significant role in the horticultural economy of Maharashtra and it is especially adapted to relatively dry agro-climatic environment when properly irrigated (Meshram et al., 2010). The Pravara River Basin belongs to the upper system of the Godavari and comprises a landscape of agriculture that is affected by surface-water irrigation and by groundwater exploitation (Central Water Commission, 2015). The Mula-Pravara basin is located over a total land area of about 4,303 km 2 and spans Akole, Sangamner and adjoining regions which are key components of the Ahmednagar district (Duraisamy et al., 2018). There is also a pronounced climatic gradient of the basin where rainfall decreases towards the eastern regions and about three-fourths of the basin lands under semi-arid climatic profile (Zomer et al., 2008). Agriculture is a significant part of the local economy and agricultural activities in the region have been given a boost through irrigation, which has opened up previously uncultivated and fallow land into agriculture (Duraisamy et al., 2018).

Since the irrigation infrastructure has been developed, it has not only affected the intensity of agricultural activities but also the decisions made by the farmers in regards to crop choice and transformation of land to farming (Landge & Kadam, 2016).The growth of commercial horticultural plantations, particularly pomegranate, in regions where traditional food crops were grown by farmers has been one of the most evident changes (Jadhav and Shinde, 2015).Greater growth in pomegranate production has been linked to greater economic benefits, to the extent that it has raised reliance on frequent irrigation during lean times (Duraisamy et al., 2018).This leads to a key sustainability question: Will horticulture be able to grow in the Pravara Basin without putting additional stress on already overstrained water resources? This question can mostly be answered by enhancing the efficiency of irrigation, managing the crop-water and the productivity per unit of water (Molden and Oweis, 2007).

Study Area:



Study Area Location Map (Compiled by The Researcher)

The proposed research is based on the Pravara River Basin as a part of a complex of Mula-Pravara of the Ahmednagar district, Maharashtra (Duraisamy et al., 2018).Geographically, the location of the basin is in the upper Godavari drainage system where the Pravara and Mula rivers begin in the western Ghats and drain to the east (Central Water Commission, 2015).The study region covers approximately 4,303 km², extending approximately between 73°37′20″–74°38′33″ E longitude and 19°02′20″–19°45′31″ N latitude (Duraisamy et al., 2018).Spatial variability in rainfall in the basin is high with the reported annual rainfall of around 508 mm in the Akole highlands and 416 mm in Sangamner (Duraisamy et al., 2018).This type of rainfall change renders irrigation a significant factor of agricultural production and cultivation decision in the area (Gupta et al., 2011).

The farming environment consists of cereals, pulses, sugarcane, and soybean among the horticultural crops with an increasing number of horticultural crops like pomegranate (Krishi Vigyan Kendra, Pravara, n.d.).

Objectives:

The present research has the following objectives:

1. To examine the development and changing spatial importance of horticulture in the Pravara River Basin.
2. To examine how irrigation growth is related to horticultural growth in the basin.

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Research Methodology:

The study is descriptive, analytical and secondary-data based, as opposed to a primary field-survey study. The Ministry of Agriculture and Farmers Welfare, Government of Maharashtra, Central Ground Water Board, Central Water Commission, ICAR publications, agricultural universities and peer-review journals (Government of India, 2024) were used to obtain secondary information. The published reports on Mula-Pravara basin assisted in comprehending the past change in land-use, the horticultural development as well as reliance on groundwater (Duraisamy et al., 2018).The horticultural development of the basin was located in the framework of the state of the horticultural development in Maharashtra and India in particular using official, horticultural statistics (Ministry of Agriculture and Farmers Welfare, 2024).

The percentage change, comparative analysis, growth-rate interpretation and descriptive statistical analysis are used in the study as the methods of interpreting secondary data.

The simple measure of interpreting water productivity is:

Water Use Efficiency (WUE) = [Crop output)/Water used.

where crop production can be in terms of kilograms or tonnes and water consumption can be in terms of cubic metres or millimetres. Even the efficiency of irrigation is determined in the study based on evidence of drip irrigation, crop evapotranspiration and crop coefficient values obtained in pomegranate under Maharashtra conditions (Gorantiwar et al., 2011). Since no field measurements were taken, the paper does not purport that the values of the calculated WUE are current farm-based WUE across the entire Pravara Basin.

Data Collection:

The significant types of secondary information adopted in the study are shown as follow.

Data category	**Major source**	**Purpose**
Horticultural area and production	Government of Maharashtra	State-level comparison
National horticultural statistics	Ministry of Agriculture & Farmers Welfare	National context
Land-use change	Landsat/AVHRR-based published research	Basin-level historical change
Irrigation development	Central Water Commission / published studies	Irrigation assessment
Groundwater status	Central Ground Water Board	Water-resource assessment
Pomegranate water requirement	ICAR / agricultural journals	Crop-water analysis
Agricultural productivity	KVK Pravara	Regional crop comparison
Climate information	Published basin studies	Agro-climatic interpretation
Sustainable agriculture literature	Books and journal articles	Conceptual framework

Horticulture Area Production Information System of the Government of India presents the official data on the harvest and area under horticultural activities as well as on the productions on the same and is a valuable source of comparative analysis (Directorate of Economics and Statistics, 2026).

The Maharashtra Economic Survey contains recent state-level horticultural statistics, such as the area and the estimates of crop-wise production (Government of Maharashtra, 2025).

Results and Discussion:

1. Expansion of Horticultural Land:

The biggest observation would be the accelerated growth of the area of horticultural plantation in the landscape of Mula-Pravara.

Table 1. Land-use change in the Mula-Pravara Basin, 1991–2016

Land-use category	1991 (km^2)	2001 (km^2)	2011 (km^2)	2016 (km^2)	Change 1991–2016 (%)
Agriculture	733.13	1,150.10	1,310.40	1,450.70	+97.8
Built-up	13.40	19.10	28.40	39.60	+195.7
Fallow land	536.30	419.80	278.10	211.80	−60.5
Forest	393.30	517.40	493.20	561.60	+42.8
Plantations	19.08	11.19	121.10	324.60	+1,601.4
Water bodies	110.20	97.20	139.50	83.70	−24.0

Source: Duraisamy et al. (2018).

- As shown in the table, the agricultural land increased almost twice over the years between 1991 and 2016 by 97.8%.
- The most peculiar modification was the expansion in land under plantations that rose by 19.08 km to 324.60 km which is an explosion of 1,601.4 percent.
- This growth is tied strongly with a shift in traditional food crops to commercially appealing crops, such as pomegranate (Duraisamy et al., 2018).
- The fallow land, which has gone down by about 60.5 per cent., is also an indicator of the growing significance of irrigation, groundwater availability and investment in agricultural land-use change.

2. Agricultural and Horticultural Productivity:

The data collected by KVK Pravara at the district level indicates that there is a high potential of horticultural crops in terms of their productivity.

Table 2. Selected horticultural crops in Ahmednagar district

Crop	Existing area (ha)	Existing productivity (t/ha)	Potential productivity (t/ha)	Productivity gap (t/ha)
Mango	14,113	7.5	9.0	1.5
Lime	12,910	12.0	20.0	8.0
Pomegranate	8,348	8.5	15.0	6.5
Guava	5,220	20.0	30.0	10.0
Onion	69,978	17.0	22.0	5.0

Source: Krishi Vigyan Kendra, Pravara.

- Those pomegranat data are especially important since the current productivity of about 8.5 t/ha is much lower than the reported potential (15 t/ha).
- This implies that the future growth of horticulture does not involve necessarily the increase of the cultivated land, but also through productivity growth on current land.
- Improved planting material, bahar management, fertigation, pest management and micro-irrigation is also important as shown by the productivity gap.

3. Water Requirement of Pomegranate:

Pomegranate is of special relevance as far as water-use efficiency is concerned since its irrigation needs can be forecasted in scientific terms using the approaches to evapotranspiration. A study undertaken in Ahmednagar district was able to satisfy the development of crop coefficients and determination of pomegranate crop evapotranspiration between the time of establishment and during maturity (Gorantiwar et al., 2011). Studies based in Maharashtra have also indicated that the pomegranate water needs differ significantly according to the age of trees, season and the stage of phenology (Meshram et al., 2012). The broad spectrum validates the idea that irrigation cannot solely be grounded on a minimum amount of water per year. Rather, irrigation schedules ought to react to the age of trees, stage of crop development, evapotranspiration, canopy formation and current weather patterns.

4. Micro-Irrigation and Water Use Efficiency:

It was specifically in the Pravara Basin that micro-irrigation plays an important role since it has the ability of providing water at the superficial area of crop root and minimizing unnecessary loss. Experimental studies on Bhagwa pomegranate have shown that there is important variation of water-use efficiency of Bhagwa pomegranate under varying settings of micro-irrigation (Sharmila et al., 2019).In the experiment a value of 1.98 to 4.01 kg m -1 was reported to be the values of the WUE in that experiment and that varied depending on the irrigation treatment.

Table 4. Reported water-use efficiency under different micro-irrigation conditions

Indicator	**Reported range**
Water used	2,520.20–8,340.60 L tree^{-1} bahar^{-1}
Water-use efficiency	1.98–4.01 kg m^{-3}
Most efficient treatment	Subsurface drip with double inline laterals
Dripper spacing associated with high WUE	30 × 30 cm

Source: Sharmila et al. (2019).

Such results apply to the Pravara Basin since they show that the mere presence of irrigation is not enough but the means through which the irrigation water is distributed can significantly affect the water productivity.

5. Role of Mulching:

Mulching poses another comparatively easy solution to the problem of lowering the amount of water being lost at the surface of the soil. A study of pomegranate grown in Maharashtra conditions identified that irrigation rates and organic mulches had an effect on crops, productivity and water efficiency (Meshram et al., 2018). Recent studies have also documented that organic mulching will be able to minimize the surface evaporation and enhance the use of water-under deficit irrigation (Meshram et al., 2026). This is especially applicable to semi-arid agricultural systems with evaporation losses, which can form a significant share of such losses.

6. Groundwater Pressure:

Another challenge that poses a significant sustainability challenge is the growth of irrigation and horticulture. Mula-pravara basin central zone has been found to be overexploited groundwater zone, which illustrates the fact that there has been no agricultural expansion without environmental cost (Central Ground Water Board, 2017). According to published studies, groundwater is a significant source of irrigation in the area and direct irrigation is provided to only a comparatively small part of agricultural land with the help of surface irrigation projects (Duraisamy et al., 2018). This reliance exposes horticulture to the losses due to depleted ground water i.e. when the monsoons are poor.

The issue is further enhanced as farmers resort to high-water-perennial horticultural plantations, as orchards need water treatment maintaining the plantation throughout the years.

7. Irrigation and Land-use Transformation:

The relationship of irrigation and horticulture in the basin is not, then, only technical; it is also geographical and economic. Better water access fuelled agricultural transformation (turning fallows and uncultivated land into agricultural land), and economic policies inspired farmers to use commercial crops (Duraisamy et al., 2018). The evolved agricultural change illustrates how irrigation infrastructure is able to indirectly determine land-use patterns. Previous studies of the irrigation projects in the Upper Pravara Basin also highlighted the need of irrigation development and stabilisation of irrigation facilities that have already been developed (Landge & Kadam, 2016).

8. Water Quality and Sustainable Horticulture:

Sustainable horticulture is concerned with water quantity but the quality of the irrigation water also has an impact on the soil and crop productivity. The study of the Pravara Left Bank Canal command area revealed that concerns exist regarding the parameters like bicarbonate, chloride, phosphate and leftover sodium carbonate in particular groundwater samples (Gadekar et al., 2016). This implies that in the long-term viability of horticultural sustainability, the water quantity and water quality must be monitored on a regular basis. The uncautious use of fertilisers may also lead to the further transfer of nutrients to ground water and surface water.

Integrated nutrient management must therefore be applied with good irrigation practices.

9. Recent Maharashtra Horticulture Context: The extended horticultural landscape of Maharashtra demonstrates the financial importance of the industry.

Table 5. Maharashtra horticulture: selected indicators, 2022–23 and 2023–24

Indicator	2022–23	2023–24	Change
Total horticultural area ('000 ha)	2,239.93	2,174.11	−2.9%
Total horticultural production ('000 MT)	32,779.58	32,688.23	−0.3%
Fruit-crop area (lakh ha)	—	8.74	—
Vegetable-crop area (lakh ha)	—	9.46	—
Pomegranate area (lakh ha)	—	1.08	—

Source: Economic Survey of Maharashtra 2024–25, based on HAPIS data.

The statistics show that regardless of the changes in the area and production of horticulture on an annual basis, it is still primarily part of the agricultural economy of Maharashtra. On a national level, the horticultural production was estimated to hit circa 353.19 million tonnes in 202324 via the third estimate of the advance estimates (Ministry of Agriculture and Farmers Welfare, 2024).

Major Challenges to Sustainable Horticulture in the Pravara Basin:

- The first key threat is the reliance on groundwater especially in those regions where the level of rainfall is insufficient or unreliable.
- The second obstacle is that rainfall is highly variable and this brings about uncertainty in the availability of water per annum.
- The third issue is the growth of commercial agriculture that consumes more water and there is a risk it may strain groundwater.
- The fourth issue is the lack of productivity between actual and feasible horticultural potential yields.
- The fifth issue is lack of proper adoption of the scientific irrigation scheduling by certain farmers.
- 6th challenge is soil and water quality risk related to the high use of fertilizer and chemicals.
- The seventh one is the economic risk that comes with reliance on few commercial horticultural crops.
- The eighth complication is the possible insecurity of the perennial orchards to the extended droughts and depletion of groundwater.

Sustainable Strategies for the Pravara River Basin:

1. Expansion of Micro-Irrigation:

Where practicable in the Pravara River Basin micro-irrigation ought to be encouraged on the economic grounds that it is also most technically feasible. Systems of drip irrigation and subsurface irrigation can also be used in order to provide water to the root zone and minimize losses by evaporation, surface runoff and deep percolation. This is especially in the cases of horticultural products like pomegranate, lime, guava and other fruits which are grown in semi arid conditions. It has been scientifically proved that suitable micro-irrigation is capable of enhancing crop growth, output and water-use efficiency. Subsidies by the government, technical training and frequent support in maintenance could encourage more adoption by the farmers. Thus, the use of larger efficient micro-irrigation systems can enable the basin to have greater agricultural production, using relatively less water.

2. Scientific Irrigation Scheduling:

Sustainable development of horticulture in Pravara River Basin requires scheduling of scientific irrigation in the region. Farmers are not supposed to administer a set amount of water at a set frequency since the crops require varied amounts of water based on the temperature, precipitation, evapotranspiration, age of trees and developmental stage of the crop. Using irrigation schedules like the crop evapotranspiration and crop coefficient values can give water as per the true need of the plant. In pomegranate orchards, e.g., irrigation needs are significantly different in young and old trees, as well as in various phenological periods. This means that weather data, moisture levels of the soils and irrigation schedules on a crop-to-crop basis must be combined in order to enhance water-use efficiency and avoid un-necessarily groundwater pumping.

3. Water Harvesting:

In the Pravara River Basin, water harvesting may have a significant impact in enhancing water security in agriculture. Rainfall could be captured during the monsoon season by use of the construction and repair of farm ponds, check dams, percolation tanks, recharge wells and small watershed facilities. The stored water can be then utilized towards protective irrigation during dry seasons, and recharge structures can be used to aid in ground water restoration. The renewal of the old water bodies can also enhance the availability of water at the local level and alleviate the strain on the ground water sources. Participation by the community is especially significant since the benefits of the water-harvesting structures can be greater than those of an individual farm. Integrated watershed where soil conservation and rainfall harvesting and groundwater recharge would be combined would thus facilitate sustainable horticultural development.

4. Groundwater Regulation:

Ground water management is needed since the expansion of irrigation and development of horticultural activities have contributed to overreliance on ground water in various areas of the Pravara Basin. Strategic groundwater monitoring and control should be done in areas with decreasing groundwater levels or those with overexploitation. Annual recharge, monitoring of extraction, and regular measurement of groundwater levels may also be useful in determining the areas experiencing stress in water. Automatic switching to water saving irrigation technologies and avoiding superfluous pumping should be recommended to farmers.

Collective decision regarding extraction can also be enhanced by means of community-based ground water management. Local institutions and farmers' organisations, working together with government agencies should come up with groundwater-management plans that can integrate both agricultural needs and long-term sustainability of the resource.

5. Crop Diversification:

Diversifying crops would minimize environmental and economic risks involved with overreliance on one prepared horticultural crop. As much as pomegranate is a vital commercial crop in the area, farmers ought to consider mixtures of fruits, vegetables, pulses, cereals, fodder and other appropriate crops depending on local soils, rain and water supplies. Farm Resilience: Diversification may enhance the resilience of farms when prices in markets vary or when a specific crop suffers because of pests or diseases or weather stress. Use of crops that are chosen based on their water needs can also minimise the stress on ground water resources. The high-value horticultural crops and rather lower-intensive-demand crops could work together in the Pravara River Basin to achieve income security and sustainable water management.

6. Mulching and Soil Moisture Conservation:

Mulching and soil-moisture conservation techniques have the potential to greatly contribute to sustainable horticulture in semi- arid climate of the Pravara River Basin. Horticultural plants may have organic mulch like crop residues, straw, leaves and other biomass readily available locally. The process of mulching lowers the evaporation into the soil surface and the temperature of soil and conservation of moisture in the root zone. It may also suppress the growth of weeds, and gradually add organic matter to the soil. Mulching can also be used together with proper irrigation and soil-management practices that decrease the amount and number of irrigation that crops need. The farmers should, then, be advised to combine organic mulching to drip irrigation and other methods of moisture conservation.

7. Precision Agriculture:

It is possible to create new opportunities in terms of water management in the Pravara River Basin with the help of precision agriculture. With the aid of technologies, including but not limited to soil-moisture sensors, automated drip irrigation, weather stations, satellite imagery, remote sensing and Geographic Information Systems, farmers can gain insights into the spatial and temporal changes in crop water demands. Irrigation can be modified based on the soil moisture, the health of the crops and the weather instead of applying the same amount of water on an entire orchard. The use of remote sensing can be used to determine the locations of water stress and the change of horticultural land use as well. Despite the fact that the initial investment in precision technologies can be considerable, through cooperative methods, government contributions, and training of farmers, the technologies can be more affordable.

8. Improvement of Productivity Rather Than Only Area Expansion:

The future horticultural areas of the Pravara River Basin need to be developed with

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an emphasis on boosting production as opposed to incessant increment in the area under cultivation or irrigation. Plantation of horticultural plants without regard to water availability may put a strain on the groundwater and other water supplies. It should then pay more attention in enhancing the yield per hectare and production per unit of water. Increasing yield on the current farms can be achieved through better planting material, scientific management of nutrients, pest and disease management, effective irrigation, mulching and better orchard management. Such a strategy is able to offer greater economic returns in addition to not necessitating similar rising of land and water utilization. As a result, the idea of more production with each unit of water should become one of the central principles of horticultural development of the Pravara River Basin in a sustainable way.

Conclusion:

The discussion reveals that horticulture has emerged as a significant aspect of agricultural change in the Pravara-Mula area. The greatest indication is the growth in the size of the plantations, which expanded by 19.08 km 2 in 1991 to 324.60 km 2 in 2016, an increase of about 1601 percent. The effects of irrigation development, the availability of ground water, and technological change and the economic appeal of commercial crops combine to produce this expansion. Pomegranate is developing to be a significant horticultural crop due to relatively good adaptation to semi-arid environment and high market interest. But, the spread of horticultural activities also puts strain on the scarce water resources of the region. The existing literature shows that drip irrigation, the correct timing of irrigation work, the use of mulching and crop-specific water management can help to enhance water-use efficiency.

Promotion or not promotion of the horticulture will not be the main concern of the Pravara River Basin, the question is how can the horticulture be developed without the thwarts on the long term availability of water? Sustainable horticultural plan must be composed of water conservation, groundwater management, micro-irrigation, management of soil-moisture, increasing the productivity and diversifying crops. The research thus concludes that future of horticulture in the Pravara River Basin relies on shifting the focus of the current strategy, which is the area expansion strategy, to water productivity and sustainability strategy.

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