Review Article

Stability and Sustainability Indices and Mitigation Strategies for Water Conservation in relative to Fruit Crops

ABSTRACT

“Water scarcity” describes freshwater resources that are insufficient to meet the needs of environment. It poses a serious threat to balance the exists between human needs and environmental constraints. In many ways, we are running out of freshwater by which food production is reduced because it consumes a large amount of water and may lead to food insecurity. The issue of water shortage must be addressed through conservation, sustainable management and technological innovation by which we ensure that everyone has access to vital resources in the future. Decreasing consumption and increasing supply are two-pronged approaches to the shortage of water. Stability indices are used when water management practices help to change the environmental condition. In fruit crops, these indices provide the ability of cultivation methods to undergo changes in water supply, climatic conditions, and other external factors. Sustainability indices include ecological, social, and economic aspects when analyzing the long-term viability of using water in the development of fruit crops. This makes it possible to strategically allocate resources and implement conservation measures. Sustainability indices evaluate water quality, ecosystem health, and water usage efficiency which go beyond simple water amount calculations. These indices provide focused conservation efforts with information, effective use of resources and long-term water security that improves the health of the environment and present demands. This review is about to explore water management which encompasses a wide range of activities, from increasing productivity and soil health to minimizing climate risks and encouraging community participation, each to guarantee the long-term viability of fruit crop farming.

Keywords**:***Stability, Sustainability, Fruits, Water Conservation, Rainwater harvesting and Mitigation.*

1. INTRODUCTION

Earth is called the water planetbecause 3/4thof the surface is covered with water. Water is an essential renewable natural resource.Around 3.5 billion years back life originated in the primeval of the seas. Today the oceans span two-thirds surface of the earth and support a diverse range of plant and animal life [1].Despite this abundance it remains essential to understand the necessity of water conservation,especially considering that ocean water is saline and unfit for direct consumption by humans.Humans consume an immense quantity of water for drinking and washing and manufacturing, emphasizing the vital need for water conservation [2]. Water conservation is important in sustainable agriculture especially for fruit crops because they are generally water-intensive. The global population is increasing day by day increase also the demand for food is rising along with fruits[3]. Due to climate change and irregular weather conditions, adequate water management techniques are becoming more crucial in cultivating fruit crops[4]. Stability and sustainability indices are used to evaluate and improve water conservation in agriculture.Stability indices evaluate a farming system's ability to withstand environmental changes and reveal how well water management techniques are implemented[5]. Long-term viabilitysystemsdetermine agricultural systems, and sustainability indices consider social, economicand sustainability issues. To attain water sustainability in fruit crops, water use efficiency must correspond to maintaining ecosystem health and the socioeconomic well-being of farming communities[6].

Mitigation strategies are critical in addressing water scarcity challenges and ensuring the sustainable cultivation of fruit crops. These strategies include a variety of practices aimed at optimizing water use, reducing waste, and improving overall water productivity [7]. Drip or sprinkler systems are examples of precision irrigation technology that allow targeted and efficient water application while preventing water loss due to evaporation and runoff.Using soil moisture sensors and weather-based irrigation scheduling improves water management precisionand effectiveness[8].The soil structure and capacity to retain water is also enhanced by using agroecological techniques that incorporate cover crops and organic matter.Fruit trees can improve water efficiency and provide additional ecosystem services toagroforestry systems that include them alongside other crops.Sustainable water conservation techniques increase fruit crop yields while also strengthening agricultural systems to response to climate change [9].In the context of evolving climate and water resource challengesimplementing these indicators and methods is crucial to maintaining a resilient and sustainable future for fruit crop production.This study examines the stability and sustainability indices essential for water conservation in fruit crop developmentand alternative mitigation measures that increase efficient water consumption while reducing environmental impact[10].

2. STABILITY INDICES FOR FRUIT CROPS

The context of water conservation for fruit crops is important for determining how resilient agricultural systems are against changes in water availability. These parameters indicate how well the system maintains output while decreasing risks connected with excess or scarcity [11]. The following are some important stability indicesfor water-saving fruit crops:

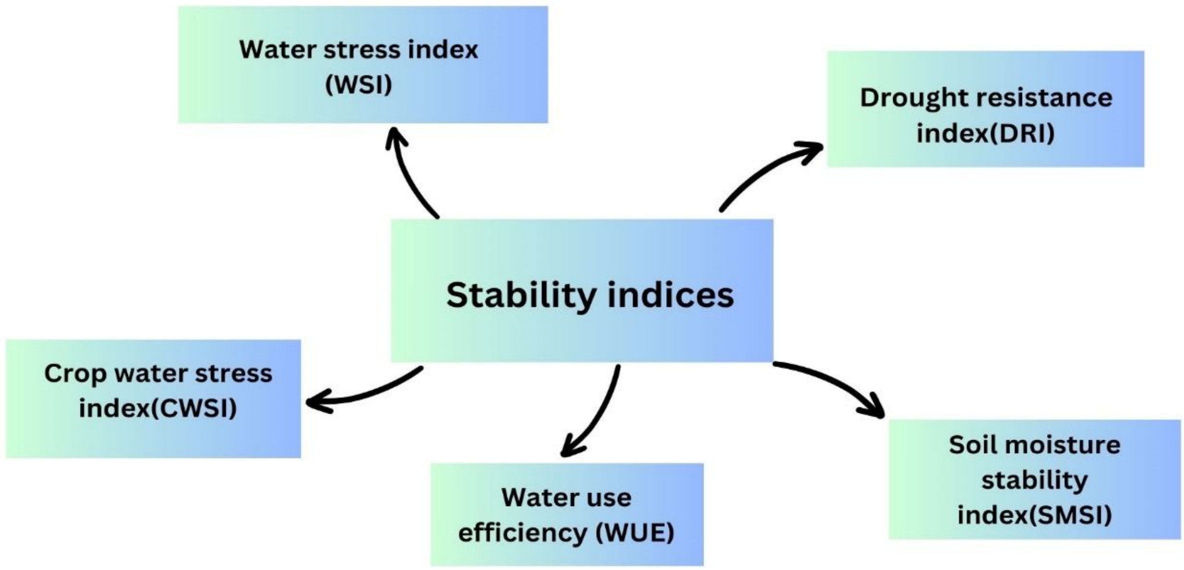

Fig.1 Stabiity indices for water saving fruit crops

2.1 Water Use Efficiency (WUE): Water use efficiency may be defined as the ratio of evapotranspiration (ET) compared to gross primary production (GPP), measures how strongly the carbon and water cycles are connected [12]. The amount of weight of fruit or biomass generated per unit of water used is measured by WUE.Improving WUE ensures optimal use of available water resources, reducing the overall water footprint of fruit crop production [13].

2.2 Drought Resistance Index (DRI):DRI assesses the ability of fruit crops to withstand and recover from drought stress. Cultivating drought-resistant varieties and implementing soil moisture conservation techniques, such as mulching and cover croppingcan enhance DRI[14].

2.3Water Stress Index (WSI):WSI quantifies the degree of water stress experienced by plants. Monitoring soil moisture levels, implementing efficient irrigation systems, and employing precision irrigation technologies help manage water stress and maintain crop stability[15].

2.4 Crop Water Stress Index (CWSI): The CWSI estimates crop water stress by combining environmental factors and canopy temperature.Real-time monitoring using remote sensing technologies can aid in timely irrigation interventions to mitigate water stress and ensure stable fruit crop yields[16].

2.5 Soil Moisture Stability Index (SMSI): SMSI evaluates the capacity of soils to retain moisture and provide a stable environment for plant growth. Practices such as organic matter incorporation, conservation tillage, and agroforestry contribute to improved soil structure and moisture retention[17].

3MITIGATION STRATEGIES FOR WATER CONSERVATION IN FRUIT CROPS:

Mitigation strategies for water conservation in fruit crops are shown in Fig.2

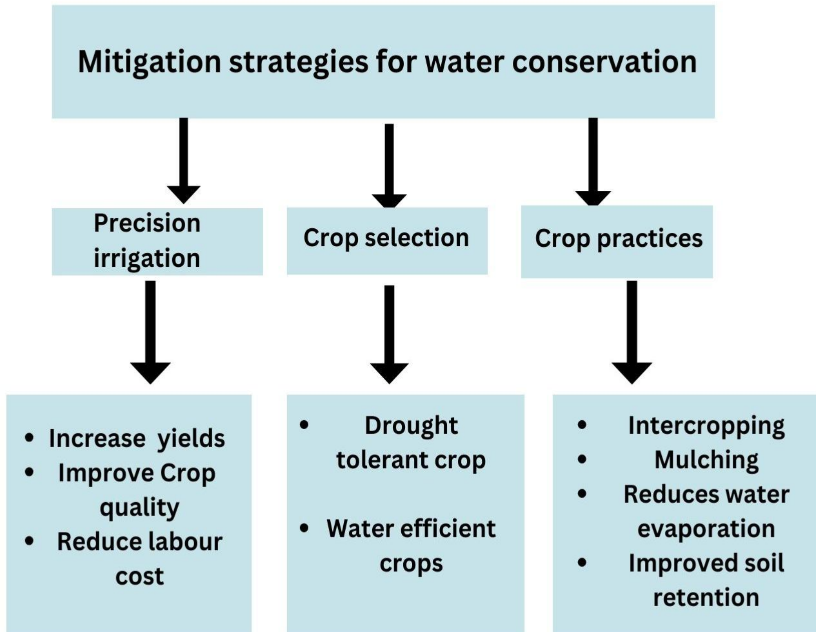

Fig.2Water conservation measures for fruit crops

3.1 Precision Irrigation:This innovative technique for watering horticultural crops uses data and sensors to provide the precise amount of water to the right spot at the right time. This technique reduces water loss, increases crop yields, and enhances the overall quality of fruits, vegetables, and flowers[8].

Advantages of precision irrigation for horticulture crops:

Water conservation**:**Precision irrigation can save up to 50% more water than conventional irrigation techniques. This is because water is only applied to crops when they require it and sprayed precisely to prevent runoff and evaporation[15].

Increase crop yield:Precision irrigation can boost crop yields by giving the right amount of water. This is because well-watered plants may photosynthesize and produce more fruits, vegetables, and flowers [18].

Improve crop quality:Crop quality can also be improved with precision irrigation. This is because plants that are not stressed by dryness or excessive watering are less prone to develop diseases or pests [19].

Reduce labour costs**:**Precision irrigation systems can be automatedsaving farmers time and effort [15].

Environmental benefits:Precision irrigation can benefit the environment by lowering water pollution and greenhouse gas emissions[20].

Sensors**:**Plant health, soil moisture, and meteorological conditions are all tracked by sensors.This informationis then utilized to determine the amount of water to apply to the crops[21].

Controllers**:**Controllers manage the irrigation system and ensure that each plant receives the appropriate amount of water [8].

Valves:Valves manage the flow of water to different portions of the irrigation[22].

3.2 Crop Selection: Selecting suitable horticulture crops can help in conserving water and promote sustainable farming[19].Some important principles to consider:

Droughttolerant crops:Choose crops that are naturally adapted to drier regions having deep root systems that can tap into deeper.Consider native or heirloom types within popular crops as they frequently demonstrate superior drought tolerance than modern hybrids [23].

Water-efficient crops:A crop that transpires less water from its stems and leaves. Examples include leafy greens, tomatoes, onions, garlic, and various herbs[24].

3.3 Cropping practices for water conservation:

Intercropping:Plant water-intensive crops alongside lessdemanding ones to create a diversified, microclimatic setting that improves moisture retention [3].

Mulching**:** Mulching is an excellent way to conserve water in horticultural crops. It entails adding a layer of covering substance to the soil surrounding your plants [25].

Reduces water evaporation:The mulch layer physically prevents sunlight from reaching the soil, which dramatically reduces water evaporation.This decreases watering for your demanding plants, especially during hot and dry spells [25].

Enchanted soil moisture retention**:** Mulch absorbs and retains precipitation and irrigation water, much like a sponge does. This provides a moisture reservoir that is easily accessible to plant roots, eliminating the need for frequent watering [26].

Mulch retains soil moisture-suppressedweed growth**:**Weeds take essential nutrients and water away from crops. Mulch invites competition and allows plants to get the most out of the water resources by preventing weed seeds from germinating and growing [27].

Mulch-suppressed weed growth regulatessoil temperature**:**Mulch insulates the soil, keeping it warmer in the winter and colder in the summer. Supporting healthy plant growth and water uptake helps maintain consistent soil temperatures [28].

Mulch regulates soil temperature additional benefits**:**Mulch can help reduce soil erosion, improve soil fertility by incorporating organic matter into the soil, and improve your garden's overall appearance [29].

3.4Choosing the right Mulch: Mulch comes in a variety of forms, each with advantages as follows:

Organic mulches:Wood chips, bark, straw, leaves, compost, and grass clippings are some of them. They are inexpensive and biodegradable, and as they break down, they enhance the quality of the soil. They might, still require more frequent replenishment [27].

Synthetic mulches:These consist of landscape fabric and plastic sheeting. They may retain heat and stop water infiltration, although they are useful for keeping weeds down and saving water. They also do not support the health of the soil [25].

Biodegradable plastic mulches:These are a more recent option composed of elements derived from plants that eventually break down. They can be more costlybut they provide the advantages of both synthetic and organic mulches[30].

Applying mulch:Mulch the area surrounding your plantbases making sure not to get mulch up against the stems to avoid rot. The recommended depth for organic and synthetic mulches is two to four inches, with a little less for the former.Resupply organic mulch as neededusually once or twice a year. Mulching is an excellent way to improve plant health, reduce water usageand create a more sustainable and productive garden design [25].

4. RAINWATER HARVESTING

Water harvesting (WH):Water harvesting is the term for this type of concentrated precipitation in a smaller area. It can be defined in several ways, including the method of harvesting rainwater naturally for useful purposes from prepared watersheds [31].

The world's freshwater supplies make up only 2.5 percent of all water resources, and the rate at which water is used is expanding faster than population growth worldwide.Many of the water resources we consume are restored by rainfall but by 2025, it is estimated that eighteen countries will use more water than possible[32]. There are yearly, frequent, and regional variations in the global climate. Floods, droughts, earthquakes, and tornadoes will occur in various parts of the world at any time. Although we cannot do something to stop these natural disasters, we can lessen their effects by being ready and organized [33]. In addition to lessening the effects of drought, stormwater runoff peak flow levels and dependency on surface and groundwater, rainwater collecting and storage can also minimize nonpoint source pollution, permit groundwater recharge, and encourage sustainable behaviors and water conservation [34]. The concept of agricultural rainwater harvesting is based on the idea of transferring precipitation from one area of the land which is typically small and unproductive to another area to increase the amount of water available to the latter which was previously insufficient and to bring this amount closer to crop water requirements to achieve an economically viable agricultural production [35].

4.1 COMPONENTS AND APPLICABILITY OF THE SYSTEM:

Catchment area/run-off area:The area of land, which can range in size from a few thousand square meters to several square kilometers, where almost all the precipitation that falls on it flows outside its bounds. It could be paved or rocky land, agricultural, or even just a rooftop [22].

Storage facility:The area that collects runoff water and holds it until it is needed for crops, animals, people, or other purposes. Storage options include: (i) below ground as in surface reservoirs or ponds; (ii) above ground as in soil moisture profiles; and/or (iii) below ground as in cisterns or groundwater in aquifers [36].

Target or use: In agricultural production, the target is the plant or the animal, whereas in domestic use it refers to human beings and their needs [37].

5. WATER USE EFFICIENCY AND FRUIT PLANTS

Water use efficiency is used to describe the relationship between water (input) and agricultural product (output) [38].

5.1 Improving water efficiency:

The primary variables that affect the efficiency and efficacy of irrigation operations are plant type, soil composition and structure, climate, and irrigation techniques used[39].

5.1.1 Crop type:

Crop type has a significant impact on agricultural water efficiency. Conservation tillage technologies, such as tied-ridging, have demonstrated considerable gains in water use efficiency for many crops. The study underlines the need for sustainable irrigation management in addressing water scarcity challenges in fruit crops [40]. The period of their entire growth season and their daily water requirements varies throughout the crops. So, one of the main factors affecting the amount of irrigation water required is the type of crop [41].Agricultural crop water usewith longer growing seasons and higher daily needs requiresa lot more water than those with shorter growing seasons and lower daily needs.Choosing crop varieties with a reduced water requirement but still providing enough added value is a crucial first step in lowering the amount of irrigation water needed [42].

5.1.2Irrigation scheduling:

The practice of applying too little or too much water to crops is lessened or eliminated with the use of irrigation scheduling. However effective irrigation scheduling requires adjusting the time and volume of water given to crops according to the crop's development stage, water content in the root zoneand the amount of water the crop has used since the last irrigation[43].One of the best ways to schedule irrigation is to measure the soil moisture content directly. Farmers' ability to use sophisticated irrigation is influenced by their labour and water availability [44]. In addition, the soil and climate of a certain area affect the amount of water available to crops. Observe that delivering too much water may have the opposite impact than planned, since crops cannot consume too much water and may become stressed owing to the reduced oxygen concentration of wet soil. Along with wasting water, this technique will squander electricity and pumping expenses. For optimal crop output and water efficiency irrigation planning must be done carefully and the amount of water used must meet the needs of the crop. The ideal amount of water is accessible to the plants when they need it which manages the soil reservoir[45].

Good irrigation scheduling necessitates an understanding of:

• Water demand through various agricultural growth cycles

• Soil moisture content and soil water holding capacity

• Climatic conditions

The amount of water needed for planting in the early season is typically 50% less than that needed for midseason planting, when the crop has completely grown and reached its peak water need. In contrast, late-season demand can be as high as peak demand for fresh-harvested crops and as low as 75% for dry-harvested plants. This irrigation schedule needs to be closely monitored by growers, and the system used for irrigation needs to be adaptable enough to meet these changing requirements[46].

5.1.3Irrigation method:Once the quantitative and temporal characteristics of optimal water demand have been determined, a method that can make such water available in the most effective way should be selected[11].

5.1.3.1Sprinkler irrigation:Sprinkler irrigation systems mimic natural rainfall.Sprinkler heads that rotate are used to force water through pipelines and spray crops. Surface irrigation is less efficient than these systemsbecause they require pressured water, they are more expensive to construct and run.Traditional sprinkler systems lose a significant quantity of water to evaporation when they spray the water into the air [47].An even more efficient option is provided by Low Energy Precision Application (LEPA). With this technique, drop pipes that emerge from the sprinkler arm carry the water to the crops. LEPA can attain up to 95% efficiency when used in conjunction with suitable water-saving farming methods. When compared to conventional systems, this approach can save up to 20 to 50% on energy expenses because it operates at low pressure[43].

5.1.3.2Drip irrigation:Drip irrigation delivers water using pressurized pipes and drippers that run close to the plants and that can be placed on the soil surface or below ground[48].Because this method just wets the immediate root system of each of theplants, it is incredibly efficient.Water-soluble fertilizers and other agricultural chemicals can also be applied precisely with this technology. According to research reports, drip irrigation can achieve up to 100% production gains, water reductions of up to 40–80%, and labour, fertilizer, and pesticide savings compared to traditional irrigation systems.There are variances in the complexity and price of drip irrigation systems. For the Middle East and North Africa(MENA) area, solar-powered pumps for drip irrigation systems offer a particularly attractive substitute Awaad [49].

6.SOIL ENHANCEMENT MEASURE

In addition to the inherent efficiencies of different irrigation methods, several additional soil enhancement approaches can be considered to improve the efficiency of irrigation practices.[50].

6.1 Proper field levelling :This method, especially useful for surface and sprinkler irrigation, helps ensure that water is distributed uniformly, minimizes runoff,and allows the water to move at its optimal speed[15].

6.2 Furrow diking :This is a different approach to lower runoff and boosts irrigation efficiency.It collects precipitation or irrigation water in little clay barriers inside furrows[3]. Even more water can be saved by conservation agriculture and residue management sincethey regulate the amount, orientation, and placement of crop and plant debris on the soil's surface.By implementing these techniques the soil's capacity to retain moisture is increased, water runoff from the field is decreasedand surface evaporation is decreased[51]. Conservation tillage works better on farms that get drip or spray watering because it can interfere with furrow irrigation systems. Adequate water distribution system measures can lead to further efficiency advantages.When water is provided to fields through canalsfor instancewater seepage can be significantly decreased by coating the canal's surface with concrete or compacted clay. Putting the canals underground or covered can help reduce evaporation losses even further [52].

7. IRRIGATED CROPPING AND POTENTIAL FOR IMPROVEMENTS

Making more effective use of water is essential to addressing the developing water scarcity since freshwater resources on Earth areessentially limited and the development of supplementarygoods for human is becoming more difficult for ecological and economic reasons. There are two reasons why food production systems will find this goal particularly pertinent [53].Firstmost of the water that is diverted by humans for different purposes across the globe comes from agricultural use. The other is the prevalent belief that agricultural water consumption is inefficient and low-value and should be decreased, especially in the face of potential rises in food demand. These factors combine to create a more competitive environment for water among many sectors of our society [54].

7.1 The concept and significance of a chain of efficiency steps :

The percentage of output to input, both expressed in quantitative units, can generally be used to determine the efficiency (E) of any industrial process. E is the product of input and output. Now, the more significant issues affecting the various efficiency processes are covered, along with possible enhancements[55].

7.2 Cover Cropping:By integrating these stability indices, farmers can enhance the resilience of fruit crop systems to water fluctuations,ensuring sustainable production while conserving water resources[56].

8. IRRIGATION WATER MANAGEMENT STRATEGIES IN ARID AND SEMI-ARID AREAS

Water use increased by 1% year over year in the 1980s globally. It is expected that the global water consumption would rise by 20–30% by 2050 relative to the present levels.This rate of expansion is expected to continue. Agriculture is by far the largest water user, accounting for 69% of all water extracted annually worldwide[57].Irrigation water managementis the process that involves monitoring and managing the rate, volume, and timing of water delivery to meet the needs of seasonal crops while also consideringthe ability of soil to absorb and hold moisture.Groundwater resources are critical in all economic, environmental, and social processes in semi-arid regions [58].

9.ORCHARD MANAGEMENT PRACTICES

By improving soil fertility characteristics such as (Soil organic carbon) SOC, microbial biomass, and soil water retention capacity, it is possible to conserve resources (water and soil) at a reasonable cost. Soil moisture can be improved by implementing various orchard management strategies [59].Conservation agriculture impacts the capacity of soils to hold water and water-saving varies depending on management practices and agroecological conditions. Orchard management practices improve soil fertility (such as organic carbon content, microbial population, and porosity). They can also enhance farm use [60]. The effect of transitioning from conventional soil management practices (soil tillage, mineral fertilizers, pruning residue burning) to sustainable soil management practices (no-tillage, pruning residue, cover crop retention, compost application) on soil microbial biomass, organic carbon (SOC), and irrigation water supply volume in a semi-arid environment [61].

10. SOIL CARBON CONTENT

Increased soil carbon concentration through sustainable management practices has positive agronomic effects (better nutrient availability, higher yield). Sustainable practices also benefit society by increasing soil carbon storage through recycled biomass or external inputs (like compost), lowering atmospheric CO2 levels.[62].Improving the carbon content of the soil may also benefit managing irrigation because it may affect the hydrological qualities of the soil. Since a sustainable olive orchardhas a vertical infiltration rate of soil water measured for the top 10 cm that is about ten times higher than that of a conventional orchard (one that is tilled, and removes pruning materials), at the end of winter, this allows for a larger water reservoir of 1,000 m3 ha-1 (2 m depth) than a conventional plot. Around 13 centimetresbelow the surface, the Plow pan was discovered[63].

11. CROPS WUE (WATER USE EFFICIENCY)

Crops with low water requirements and high WUE, such as CAM (Crassulacean Acid Metabolism), can be useful in semi-arid or arid areas. Compare the water use efficiency (WUE) of two nearby cacti: Opuntia *ficus-indica* (cactus pear) and *Cereus peruvianus* (bubo). As in the case of Israel and other desert nations, they also suggested that much more research and development be done to adapt more CAM species including diverse cacti as new crops for locations where water is a limited resource for agricultural development. As global warming progresses, this discovery is predicted to become more significant and influential [64].

12. DEFICIT IRRIGATION STRATEGY

Many irrigation systems and agronomic techniques are used to enhance the quantity and quality of fruit produced from a variety of crops.In orchards, irrigation applications can be decreased below crop water requirements to enhance fruit quality, minimize unwanted vegetative growth, and boost water productivity. Irrigation applications may be reduced below the crop water requirement in orchards to improve fruit quality, reduce undesired vegetative growth, and increase water productivity [65].These incisions can be made at all juncture in the harvesting cycle (monitored shortage drenched, or RDI) or at distinct phenological points. While the lack of watering does not harm fruit-generative outcomes, it islabeled as a persistent shortage of watering or SDI. It is ideal to utilize watering resolutions that are not focused on the total water necessities of crops to utilize water more judiciously and capably[66]. The prime technique is shortage watering, wherein crops are endowed with a definite extent of water deficit and produce deficiency [18]. Particular Root-Zone Drying (PRD) and governed shortage watering (RDI) are two strategies that boost fruit caliber without influencing produce; they depreciate tree vigor[67].The consequences of inadequate watering approaches on fruit grove output have been investigatedand analysed across various fruit variants and geographical zones. Multiple studies have denoted that although sustaining or even escalating fruit produce, RDI depletes tree vim, elevates water utility efficiency, and conserves watering.APRI (Alternative Partial Root-Zone irrigation) and Partial Root-Zone Drying (PRD) were developed with significant effort to improve crop water usage efficiency and fruit quality in horticulture crops[68].

The term "collection of runoff for its productive use" (WH) in hydro-agronomy refers to a broad range of techniques for gathering and condensing different types of runoff. Most of the precipitation water and a portion of the land will become productive during the WH process since the run-off-producing area is close to the cultivated area [69].The ability to produce agricultural products is more crucial, and WH systems can be designed for single- or multi-purpose applications that benefit the environment, animals, agriculture, and homes[70].Analysing the archaeological data reveals evidence of WH constructions dating back to 4500 BC in southern Mesopotamia and Jordan, where they are thought to have been built more than 9000 years ago. [71].

13. CONCLUSION

Stability and sustainability are pivotal for efficient water conservation in fruit crops Mitigation strategies are critical in addressing water scarcity challenges and ensuring the sustainable cultivation of fruit crops. These strategies include a variety of practices aimed at optimizing water use, reducing waste, and improving overall water productivity. To minimize the risk of extreme weather conditions innovative solutions need to be used for instancedrip irrigation, sustainable agriculture, zero-budget natural farming, no-till technology, night irrigation practices, mulching, zero tillage, etc. According tothe "NitiAayog" recommendationa nationwide information, education, and communication campaign needs to be launched to make the farmers aware of the positives of the adoption of micro-irrigation systems. India's water issue calls for quick action and coordinated efforts. A comprehensive approach is necessary to address the complex challenges that include pollution, climate change, overexploitation, and other issues. Government programs like the "Jal Jeevan Mission" are a positive start, but obstacles like poor infrastructure and complicated laws still need to be resolved. A comprehensive approach is required going ahead, one that incorporates effective agricultural methods, rainwater collection, watershed management, and groundwater assessment. Furthermore, there must be public awareness campaigns, institutional reforms, and a national commitment to water conservation. India can move towards sustainable water management, guaranteeing a safe and just future for everyone, with the help of the correct laws, community involvement, and technology advancements.

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