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TOWARDS A MORE HUMAN-CENTRED WATER RESOURCE MANAGEMENT: A REVIEW

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Abstract

Inefficient utilization of water in irrigated agriculture and other water management sectors have been reportedly linked to inappropriate water application and/or sharing methods, hydrological uncertainties, and decayed infrastructures. However, a problem that has been affecting the irrigation and other water management sectors which attracted little attention and remaining elusive, is the impact of unlawful human activities. Some of the human activities that have been reported to adversely affect irrigation and other water management sectors include unauthorized water uses, water wastage behavior, and excessive operational losses. Others comprise discharging poorly or untreated wastewater into watercourses, over-application of chemicals, collusions, and other forms of corruption. To change the current water governance for achieving the sustainable development goal number 12, aimed at ensuring sustainable natural resources consumption and production patterns, the impacts of such undesirable human activities need to be assessed and incorporated into water management operational analysis quantitatively.

This paper reviewed and reported two important aspects that need to be considered before putting human-centered water management into practice. 1) Ethical considerations in water use and management which need to be studied, revisited, and revised. 2) Human behavior-induced cases that have occurred and hampered the success of irrigation and other water management sectors. An insightful knowledge was gained from the review that drought condition (the state of water availability) affects water users' level of compliance with rules.

This paper, therefore, identified the impact of human unlawful activities as the missing link that if not quantitatively incorporated could render irrigation and other water management sectors unproductive. For example, a model that simulates water management operation whilst coupling the impact of humans quantitatively would be a valuable tool for prudent decision-making. It is, therefore, strongly recommended to be incorporating the impact of human activities on irrigation and other water management performance analysis quantitatively.

Keywords: Human-centred; Irrigation scheme; Management; Water resource

1. INTRODUCTION

The quest for sustainable natural resource utilization is an essential part of the ongoing 2030 agenda for sustainable development goals (SDGs). It is one of the 169 agreed targets being aimed for monitoring and assessing the level of sustainability with which resources, such as irrigation water, are being managed (Osborn *et al*., 2015; Bartram *et al*., 2018). To change the current water governance regime for achieving the SDGs' goals, an international decade for action was launched (2018–2028) and themed '*water for sustainable development* (UN-Water, 2018). This is in response to concern about how to sustainably utilize the limited water resources in the face of rapid socio-economic development and climate change, particularly in agricultural sectors. However, a problem that has been affecting the water sector, and attracted little attention, while also remaining elusive, is the impact of unlawful human activities (Groenfeldt, 2013; Shanono et al., 2020). Some of the reported activities adversely affecting the water sector include unlawful water abstractions, improper water usage (wastage); poor acceptance of water re-use measures, and excessive operational losses. Others comprise contamination of water bodies by discharging untreated or improperly treated wastewater, over-application of chemicals in agricultural activities, and fraudulent system operation (Plummer & Cross, 2006; Hermann-friede et al., 2014; SABPP, 2013; WWAP, 2017). Although adherence to water ethics in addressing these undesirable human activities thereby achieving water management goals has been stressed (Falkenmark & Folke, 2002; UNESCO, 2011), to date, these issues have not been explicitly addressed.

In water-stressed countries such as South Africa, reservoirs are a major feature of the water resource systems, and reservoir operation is, therefore, an essential aspect of the country's water management. Reservoir operation is a challenging water management task, and when behavior-driven problems arise, it may turn out to be even more complicated. The South African Department of Water and Sanitation (DWS) identifies unlawful water use as one of the major problems affecting the water sector. However, many stakeholders consider the low implementation level of water laws as the main cause of these problems (DWA, 2012). According to Mckenzie *et al*., (2012), the total water loss in South Africa amounts to 31.8 % of which 6.4 % is considered as commercial losses due to unlawful use and meter inaccuracies. The annual total water loss and water loss due to unlawful use are estimated to be 1,366 and 275 million m^3 respectively. Illegal abstraction locations exist, and several of them were identified in the farming areas of the Western Cape Province in 2017 (Philanda, 2017).

Although freshwater is plentiful in some parts of the world, it is scarce in some regions such as Southern Africa (Basson e*t al*., 1994). To address the potentially conflicting water demands in such regions, water managers need to account for all losses, thereby improving the performance of existing reservoirs (Yu *et al*., 2013; Kuria & Vogel, 2014). Such non-structural risk reduction measures have been identified as an imperative option, due to limited sites for constructing new reservoirs (Basson & Van Rooyen, 2001; Ndiritu, 2005; WWAP, 2018). South Africa is a water-stressed country, due to several factors including droughts, socio-economic growth, unlawful water use, and excessive operational losses. It has been predicted by the Department of Water Affairs and Forestry (DWAF) that unless consumption patterns change, by 2025 the country may not be able to sustain its water demand (DWAF, 1997). Studies revealed that the country's demand-supply deficit could reach 17% by 2030 if the demand continues to grow at the current rate (DWS, 2018; Colvin & Muruven, 2017). This agrees with the assertion that water demands are expected to escalate in countries with emerging economic development, such as South Africa (WWAP, 2018). Moreover, South Africa faces the most severe surface water scarcity in Sub-Saharan Africa (Burek *et al*., 2016). As of January 2018, the DWS categorized the flow in 243 (43%) of South Africa's 565 rivers as low or very low, which means the country's overall water crisis is not limited to the Western Cape (Donnenfeld, 2018). Several studies have highlighted the risk of water scarcity in Southern Africa (McMahon *et al*., 2007; Pietersen *et al*., 2008; Wada *et al*., 2016). Hence, in water-stressed countries like South Africa, there is a need to employ all necessary measures that could reduce water demand including human-induced cases thereby increasing its availability.

2. THE ETHICS OF WATER USE AND MANAGEMENT

Human beings are the major agents for changing the state of the natural environment. Thus, the quest for limiting the adverse human effects and sustainable utilization of natural resources such as water necessitates a distinctive ethical explanation (Jennings *et al*., 2009). In the 19th and 20th centuries, issues related to water rights, led to some ethical explanations on the moral philosophy of water management, drawn from ethics theories such as utilitarianism - *actions based on the benefits* and deontology - *duty based on virtuousness* (Kordig, 1974; Wescoat-Jr, 2013). Ethics are codes of conduct governing human behavior with which human actions are judged as either ethical or unethical (Ssonko, 2010; Cameron *et al*., 2004). Globally, ethics-centered approaches such as water conservation campaigns and participation, monitoring compliance, and enforcement, policy dialogues, legal actions, and other demand management measures have been reported to improve water management performance (Liu *et al*., 2009; WGF, 2000, 2016). Conversely, unlawful human activities are reportedly linked to the deterioration of the water sector (Plummer & Cross, 2006; Hermann-friede et al., 2014; SABPP, 2013; WWAP, 2017)**.** The majority of the current water management policies were developed based on utilitarianism (Miller, 2007). To develop robust and sustainable water management policies, human and water systems need to be studied and analyzed in tandem thereby assessing the impact of various anthropogenic activities on water systems, as envisioned in the concept of socio-hydrology (Sivapalan *et al*., 2012; Montanari *et al*., 2013). As expounded in the fields of water and environmental ethics (Groenfeldt, 2010; 2013; Odume & De Wet, 2016), socio-hydrology also seeks to attain sustainable water management by ensuring the needs of both humans and the ecosystem.

It has been reported that the power of technology in modifying the world, could increase peoples' propensity for unlawful activities, making ethics increasingly important in the 21st century (UNESCO, 2013). Ethics are the codes of conduct governing human activities which involves methodizing the concept of right and wrong conduct, as reflected in people's actions (Ssonko, 2010). Applying the concept of ethics can take care of ethical issues from technical, environmental, economic, social, and climate change impacts such as floods and droughts, thereby creating credibility and uniting people through sound leadership. When a society attains these values, the ethical climate is said to have prevailed, and positive responses are always expected from that society. The ethical climate of a given organization is the overall view of the moral atmosphere within that organization (Treviño *et al*., 2006). It is therefore desirable that such ethical/moral atmosphere is created in the management of water especially during poor hydrological conditions (droughts).

Water users have been blamed for aggressive habits toward maximizing usage especially during resource shortfall due to drought, which commonly leads to resource failure (Ostrom *et a*l., 2002). The majority of the water users are known to operate for maximizing production (profit) and can be viewed through the lens of egoism ethical theories – *actions based on self-interest to maximize utility* (Persky, 1995; Monroe, 2001; Miller, 2009). Hence, there is a need to consider human behavior and actions as an integral part of the water management component (Odume & de Wet, 2016; Shanono & Ndiritu, 2020)**.** One of the causes of changing human behavior is the perception of risk which was considered as an inherent part of decision-making (Williams & Noyes, 2007). According to Kinzig et al. (2013), the perceived level of risk by a given society can interrupt and change that society's established norms and values (behavior). Several studies have been conducted on the impact of human activities on water resource systems, or how people respond to hydrological extremes (floods and drought). However, it is only recently that the impacts resulting from the interactions and feedbacks between humans and water have been formalized (Sivapalan *et al*., 2012). For example, in years of drought, farmers' risk perception is expected to intensify which can drive users to disobey the water sharing rules (N.J. Shanono, 2020). This theory of human-drought interaction if further studied could contribute toward answering science question 2 of *Panta Rhei* (McMillan *et al*., 2016; Montanari *et al*., 2013)**.** The question stated that: "*How do changes in hydrological systems interact with, and feedback to both natural, and social sub-systems driven by hydrological processes*?"

3. HUMAN-DROUGHT INTERACTIONS: EXPERIENCE FROM CASE STUDIES

Reservoir yield analysis is a technique for assessing yield potential under the anticipated range of varying conditions such as hydrological and infrastructural constraints, reliability of supply, and operating rules (McMahon *et al*., 2006; Shanono et al., 2015). In conventional reservoir yield analysis, it is typically assumed that yield falls below target draft only in times of drought, but this is not always the case as human activities, such as unlawful water abstractions, can also affect yield significantly. When a water year experienced drought conditions, reservoir operators responded by implementing various adaptive strategies, such as imposing supply restrictions. In restriction periods, some users are expected to comply, whereas other users could decide to abstract water unlawfully (Shanono et al., 2019). Such human-drought relationships could significantly impact reservoir yield performance. Thus, a decrease in reservoir storage is expected to generate concern that can change the state of water users' level of risk perception. Awareness campaigns and law enforcement, in addition to whistleblowing by co-water users, can help reduce these problems.

A case in point is that Di Baldassarre *et al*., (2017) developed a model that simulates and relates the co-evolution of water abstraction from a reservoir and hydrological extremes (floods and droughts). The model revealed how reservoir storage changes due to human activities characterized by massive water withdrawals amid resource shortfall (drought) or less water withdrawal in time of excess water (flood). Other studies have also discovered that the increased severity of drought increases the rate at which water is abstracted, due to the perceived threat to users' quality of life (Elshafei *et al*., 2014; Firoz *et al*., 2017). According to Elshafei *et al*., (2014) whenever the available amount of water decreases, and water users become well aware of the situation, the users' perceived risk increases. Also, the drier and hotter a year is, the higher the evapotranspiration, and thus the higher the crop water requirement becomes (Abbas & Chowdhury, 2016). This will instigate irrigation water users to demand more water, which could enhance their concern over a perceived water shortage. Therefore, it can be ascertained that the hydrological state can change the level of irrigation users' perceived threat to their farming activities, and financial state. Such changes in the users' risk perceptions are also expected to subsequently change their level of compliance with the water allocation rules. Hence, hydrological conditions can affect users' perceived threat, which can generate more concern, and subsequently, change their compliance behavior.

Another case in point, which can be linked to the dynamics of human-drought interaction, is the well-known 2016 water scarcity crisis of the city of Cape Town, South Africa. Water conservation and water demand management (WC-WDM) measures were implemented, and a considerable reduction in consumption was recorded from 2011 to 2014. It was then presumed that no water resource development was needed until 2024 if water users in the city maintained this behavior. However, in 2015, the city's water consumption significantly increased, due to a change in users' behavior with regard to the WC-WDM measures. The situation was also suspected to have been exacerbated by the failure to impose restrictions on time, and over-abstraction by agricultural users due to perceived risk as a result of a prolonged drought condition in that year (Muller, 2017). This reveals that the interplay between humans and drought is highly uncertain but essential to be incorporated into both water management strategies and operations.

Sub-Saharan African countries such as South Africa and many other countries across the globe are water-stressed, due to several factors including droughts, socio-economic growth, unlawful water uses, and excessive operational losses. Studies revealed that South Africa's demand-supply deficit could reach 17% by 2030 if the demand continues to grow at the current rate (DWS, 2018; Colvin & Muruven, 2017). This agrees with the assertion that water demands are expected to escalate in countries with emerging economic development, due to not only demand dynamics but also drought impacts coupled with unavoidable human behavior (WWAP, 2018). Although some non-structural risk reduction measures like WC-WDM are in place in some countries, there is a need to dynamically consider the impacts of anthropogenic activities relating to water use. To achieve this, the causes and effects of human responses to hydrological extremes (droughts and floods) need to be explored, well-understood, and realistically incorporated into analysis for decision support. It is important to note that the primary cause of this problem is resource shortfall (drought), which is linked to the escalation of water consumption due to users' perceived threat to their quality of life (van Oel *et al*., 2008; Elshafei *et al*., 2014; Firoz *et al*., 2017). Also, ineffective water laws enforcement and other situational factors related to water users, surveillance systems, and other infrastructural constraints contributed immensely to this problem.

Other human factors that directly represent the level of users' moral awareness, understanding, and cooperation, especially in drought periods need to be considered. Moral or ethical awareness is the ability of an individual to identify his deliberate action, and figure out what consequences that action could cause to others, and understand his instinctive feelings (De Cremer *et al*., 2010). Humans' decisive actions, which can have positive or negative impacts, can be categorized as either ethical or unethical respectively (Cameron *et al*., 2004). Ethical decision-making and action is the people's will to adhere to commonly accepted rules, as in allocating valuable resources such as water. Thus, for an individual to make a decision that is ethical or not, depends on whether that individual is morally aware of the consequences (Tenbrunsel & Smith-Crowe, 2008). Such a decision can lead to either moral or immoral practices and depends on an individual's motives (self-interest or fairness), shaped by some inherent factors (Tenbrunsel & Smith-Crowe, 2008; De Cremer *et al*., 2010). These factors comprise culture, awareness or knowledge, religion, social well-being, and other societal value-related attributes known to shape individuals' moral thinking, and actions (Treviño *et al*., 2006). These socio-cultural values are known to influence how new, and innovative policies are received, and adopted by indigenous societies (Akiwumi, 1998). These factors also affect personality characteristics such as trust or distrust, as in accepting and complying with newly introduced natural resources conservation and sharing policies (Rim-Rukeh *et al*., 2013).

4. CONCLUSION

Although considerable studies on the effect of human behavior on water management have been conducted both in research and in practice, its impact on water management is rarely modeled and quantified. Also, the effectiveness of a given water management policy can have impacts on human behavior, it is only recently that research on the interactions, feedbacks, and co-evolution of the coupled human-water systems has been formalized and termed as socio-hydrology. A model that simulates water management operation whilst coupling the impact of humans quantitatively would be a valuable tool for prudent decision-making. Globally, there are different approaches to water management-related studies, such as environmental management, socio-economic, climate change, and policy perspectives. However, the effectiveness with which water is being managed and utilized with due consideration to the impacts of human behavior is missing in the earlier and current literature. Realistic incorporation of the concepts of ethics into irrigation and other water management operation can help in achieving the water management goals. This is in line with the calls to explicitly incorporate ethical issues (social) into the water resources management (hydrology), and the recent call to the socio-hydrologists to broaden the modeling to the level of individuals' intention and action. This paper identified the impact of human unlawful activities as the missing link that if not quantitatively incorporated could render irrigation and other water management sectors unproductive. Thus, it is recommended to be incorporating the impact of human activities on irrigation and other water management performance quantitatively.

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EVALUATION OF WATER ACCESSIBILITY, DISTRIBUTION, WATER USE POLICIES AND MANAGEMENT IN KENYA

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Abstract

Water is life; every living creature needs water to continue living. Recently, access to clean water for sanitation and consumption uses is a basic right for sustainable livelihood. Kenya has less than 1000 m3 per capita of renewable supplies of freshwater making it a water-scarce country as per the United Nations classification. In Kenya, climate change, and a high population growth rate has led to less availability, accessibility, quality, and quantity of water to meet human needs. Inadequate water poses a greater risk to food production, human health, energy production, economic development, and poverty reduction thus jeopardizing the achievement of the Sustainable Development Goals. The severe water crisis in Kenya has been due to some causes like drought, deforestation, floods, land pressure from population growth, water contamination, lack of proper water management measures, and ineffective water policies. Kenya continues to face challenges concerning the allocation, distribution, and management of its water resources to satisfy sectoral demands. This paper uses secondary data to evaluate the state of water accessibility and availability of water, economic analysis of water, water management policies, and problems facing water management in Kenya, and to provide recommendations to identified problems.

Keywords: Kenya, Water policies, Water costs, Water management, Water

1.INTRODUCTION

Kenya has a landmass of approximately 592,000 km^2 of which 80% is semi-arid and only 20% is arable. Kenya, being an agricultural country, relies heavily on water as a basic factor to enhance her development for her expanding economy. The renewable freshwater sources have an annual quantity estimate of 30.7 billion m^3. The recommended global water supply per capita is 1,000 m^3/person per year but Kenya has approximately 696 m^3 /person per year, which makes her a water-scarce country. It also shows that there is a 2.3 m^3 water consumption difference since Kenyans consume about 33 billion m^3 of water (Aquastat, 2016). The average per capita water consumption in the world is around 800 m^3 per year. Countries with less than 1000m^3 per capita water consumption are considered to water-scarce thus qualifying Kenya and most countries in Africa to have water scarcity. 1.4 billion people, which corresponds to approximately 20% of the world's population, lack sufficient drinking water and 2.3 billion people have difficulty accessing clean water and sanitation. Some estimates suggest that more than 3 billion people will face water scarcity by 2025. The challenges resulting from water scarcity are evident in urban informal settlements and rural areas where residents are unable to access piped water. The demand for water in various sectors in the country; industry, wildlife, infrastructure, hydropower, domestic use, and agriculture for activities like irrigation that cause water menace in Kenya. Within the past five years, water coverage has only indicated a mere 4% per year increase margin even though in 2015, the National Water Service Strategy (NWSS) had targeted to achieve 80% coverage. The current countrywide water coverage is at 55% (Kenya's National Water Master Plan 2015).

1.1 Water Accessibility and Availability Concerning Population Growth in Kenya

Access to clean and safe water is a basic human right and everyone has a right to a clean source of water. The third target under Millennium Development Goal (MDG) on environmental sustainability, aims at improving access to sustainable water and better sanitation. An individual is required to have access to water if he/she can access at least 20 liters of water within a radius of one kilometer (WHO, 2000). Between 2010 and 2015, access to sanitization and water services slightly increased in the country. In 2015, about 63% of Kenyans that is 57% in rural areas and 82% in urban areas had an access to improved drinking water as compared to 2010, which had 60% that is 53% in rural areas and 83% in urban areas. Improvement in water accessibility has been driven by the increase in access to piped water in rural areas. However, the proportion of the urban population accessing piped water fell between 2010 and 2015 from 47 percent to 45 percent (WHO/UNICEF 2015).

UNICEF and World Health Organization discovered that only 59% of the Kenya population has access to basic water services (WHO/UNICEF 2015). . The poor Kenyans in cities have the majority of the population living in informal settlements where they only access polluted water, exposing them to waterborne diseases like cholera deteriorating their health. By the year 2025, it is approximated that Kenya will have 235 m^3 per year water availability, two-thirds of the current availability caused by the continued increase in population. Kenya might face severe economic water scarcity beyond 2025 because of rapid population growth (The WASH Joint Monitoring Programme Report 2019). Surface water and groundwater are the main sources of the piped water in Kenya. The surface water sources include reservoirs, large dams, and rivers. The reservoirs have a storage capacity that can regulate river runoffs and pumping off take facilities in small dams, rivers, and some lakes. Kenya has two types of rivers that are the seasonal rivers in arid and semi-arid areas and perennial rivers found in coastal, western, and central parts of the country. River flooding is also common during the long rains, however, the metrological department in Kenya has been attempting to study and record floods as they happen to prevent future effects of such floods (Mutui et al. 2016).

The groundwater in Kenya is found in deep aquifers that are up to 300 meters. Nairobi area is a good example of such an aquifer and it is the largest even though the aquifers in all regions of

Kenya are 150 meters deep on average. The most important determinant of the groundwater is the Kenya hydro-geological units. The major challenge facing the country is the lack of funds for the construction and maintenance of strong water piping systems causing more than half of the population to lack access to piped water. Those who have access to piped water get contaminated water since the pipes are poorly constructed or are vandalized (Maino, 2011).

Table1:Percentage of water usage in different sectors in Kenya

Sectors	**Percentage of water used**
Agriculture	80%
Service industries	12%
Mining and quarrying, manufacturing, constructions, and energy	8%
Total	100%

Source: United Nations (2017) Kenya; SDG 6 Data

The main water catchment basin areas in Kenya are Lake Victoria, Rift Valley, Athi River, Tana River, and Ewaso Ngi'ro North Basins as presented in figure 1.

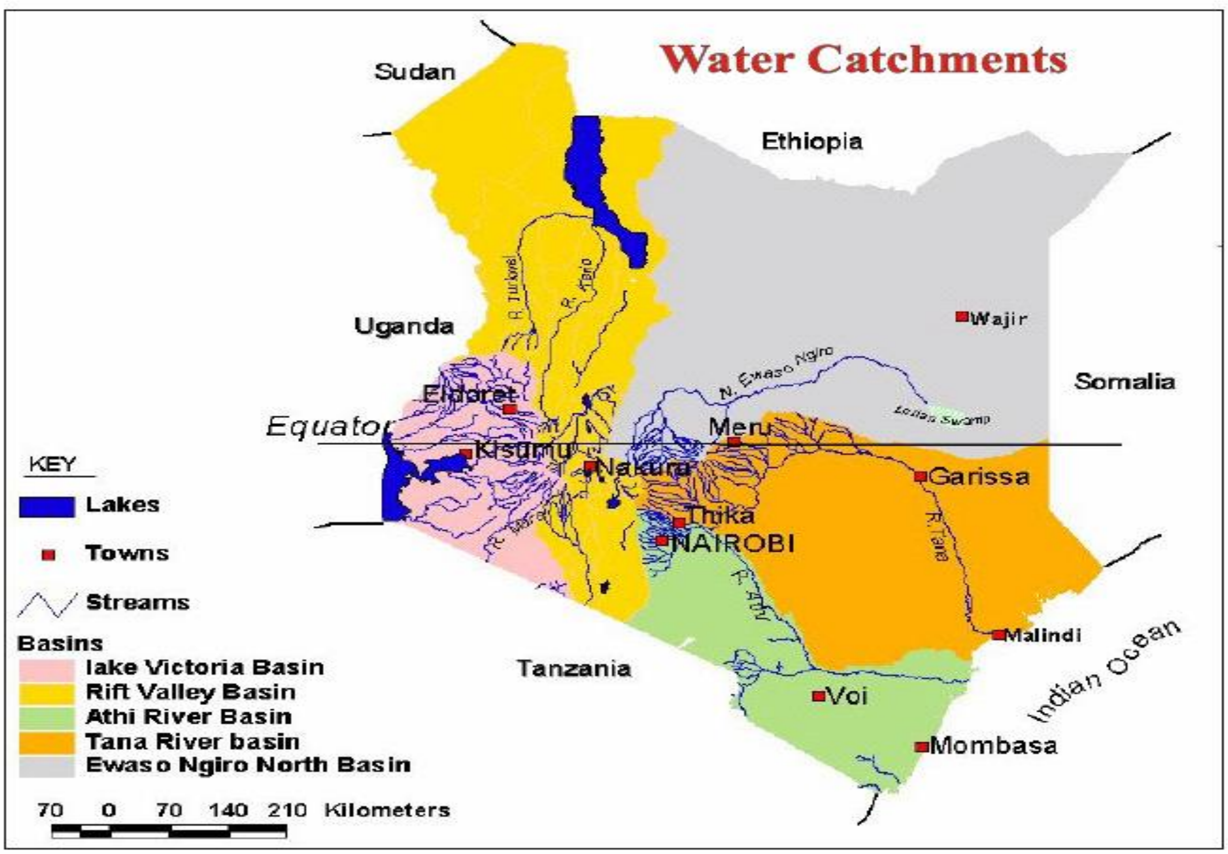


Figure 1: Kenya map showing major catchment areas from the Ministry of Water and Irrigation

2.METHODOLOGY

The study used a descriptive survey design. This design enables a researcher to conclude one transitory data collection to extrapolating what might happen again in a similar circumstance. Descriptive design is chosen since it focuses on data instead of theory. This study used secondary data sources. Secondary data is hard to manipulate as opposed to primary data that is prone to manipulation by the researcher. Data was collected from journals, articles, and water agencies like the Ministry of Water and Irrigation, Water Services Regulatory Board (WASREB), Water Resources Management Authority (WRMA), and Water Services Trust Fund to the Water Sector Trust Fund (WSTF). The content analysis method analyzed qualitative data and descriptive statistics like frequency and percentage analyzed quantitative data.

3. FINDINGS AND DISCUSSIONS

3.1 Sources of Household Drinking Water

Table 1 shows the sources of Household Water drinking Kenya in Kenya. According to NEMA (2010). Mount Elgon, Cherengani Hills, Mount Kenya, Mau Forest Complex, and Aberdare range are the five water towers where most of Kenya's water comes from. They are the largest mountain forests and the sources of main rivers in Kenya. The majority of households in Kenya (88.2%) urban centers and (59.1%) rural centers obtain drinking water from an improved source, while (10.1%) urban centers and (39.2%) rural centers use non-improved sources. The majority of people in urban centers use improved sources. The most common source of drinking water in town centers is piped water into the residents, dwelling place/plot/flat while in rural areas, the main water source is surface water followed by piped water into the homes, plot, flat, or yard. Almost 4% of all households in urban centers in Kenya have water piped in their premises while the majority of people in the rural areas have to walk for almost 30 minutes to fetch or buy water from various water vending points. Slightly more than half of the households in Kenya do not treat their drinking water which might expose them to waterborne diseases like Cholera. The commonly used water treatment methods are boiling and adding chlorine and other water treatment agents. Generally, 45% of households use suitable water treatment methods. If water is not available on the premises either through piping or drilling boreholes, households either collect rainwater or fetch from springs, rivers, dams or buy from water vendors. In rural areas, the collection of water is delegated to the women and young girls.

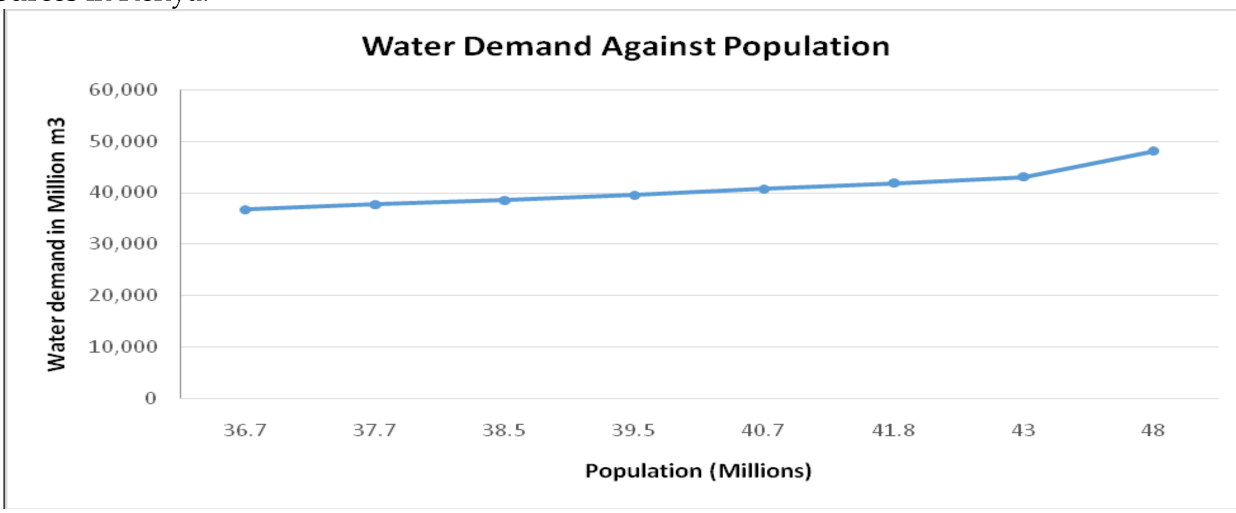
Table 2: Sources of Household Drinking Water

Sources of Water	Urban (%)	Rural (%)
Improved Source	88.2	59.1
Piped water into the homestead	45.5	15.0
Public tap	24.8	9.3
Public well /borehole	3.8	8.2
Protected well/borehole	3.9	10.3
Protected spring	3.4	11.6

Rainwater	2.6	4.5
Bottled water	4.3	0.2
Non-improved source	**10.1**	**39.2**
Unprotected well	1.7	8.8
Unprotected spring	1.2	5.5
Tanker truck	3.1	0.8
Surface water	4.1	24.0
Others	1.7	1.7

Source: *Kenya's National Water Master Plan (2015)*

Figure 2 indicates a positive correlation between water demand and population growth. As the population increases, water demand keep on rising, the pressure on natural water sources keeps on increasing. With a positive correlation, a high population poses a great threat to already scarce water resources in Kenya.



Source: *African Ministers' Council on Water (AMCOW) annual reports, Ministry of Water and Sanitation (2018).*

Figure 2: Population growth and total water demand for all sectors

3.2 Economic Analysis of Water in Kenya

Water conservation is a method of tapping as much water as possible and storing it in tanks or reservoirs. Kenya, like many African countries, might not achieve the Sustainable Development Goals and other national goals like Vision 2030 and development targets if the existing water scarcity condition prevails. Agriculture, forestry, fishing, tourism, and mining contribute to over 40% of Kenya's gross domestic product (GDP). These sectors depend on freshwater. WASREB's role in setting water tariffs is the most suitable way of ensuring water sustainability. WASREB uses tariff adjustments as a crucial economic instrument for enhancing efficiency in water use and safeguarding the financial sustainability of water service providers. The board ensures that the tariffs are just, suitable, easy, and encourage water conservation. Cost-conscious tariffs help providers to effectively carry out their operations without disappointing their customers. It helps them to meet the operation and maintenance costs ensuring a constant flow of water (WASREB, 2015).

3.2.1 Financial Water Costs

In Kenya, the cost of connecting water through the pipes is very high at $400 which is unaffordable to most households. This is worsened by the fact that the water companies do not give the potential customers the option of paying gradually unlike other essential providers like Kenya Power. The connection must be paid in full before the water connection. Compared to developed countries, the cost of water is generally higher in Kenya and Sub-Saharan Africa. For instance, water from Nairobi Water costs between 19–54 Kshs/m3. A household without access to piped water from the public water companies either buys water from tankers, boreholes, or bottled water from water supermarkets and shops. Tankers sell water at 450 Kshs/m3, 5-50Kshs per 20 liters jerry cans, and 50Kshs per liter of bottled water (African Development Fund, 2015).

Figure 3: Shows residents getting water into their jerry cans from water kiosks in a rural area.

Piped water in comparison with buying water from tankers and other water vendors is much cheaper. Households who buy water away from their houses/ yard/plot pay water periodically not volumetrically. Periodically meaning paying for every liter purchased while volumetrically means paying for cubic meters whereby a bill is given after a given period. Households whose main water source is piped water spend approximately Ksh. 410($4.8) while those who source water from water vendors spend almost four times this amount that is approximately 1600Kshs monthly (World Bank, 2015).

Figure 4: Shows a water vendor (Nairobi) supplying commercial establishments with water on his cart using jerry cans previously filled at water deport/storage tank/borehole.

Due to frequent water rationing especially in big cities like Nairobi, Kisumu, and Mombasa, households are forced to buy water from water vendors that increase their monthly budget for water. The frequent rationing results in water scarcity in households and the only option is sourcing water from tankers or other water vendors depending on their buying ability. Water vendors do not have constant charges, unlike state-owned water companies. Their charges vary depending on where they operate from and the economic status of their clients. Some households buy more than 10 jerry cans daily during rationing but water vending does not exist during the rainy season this could be due to the fact that the water volume in water sources is usually high in the rainy season and low in the dry season

3.2.2 Capital Costs

To cope with water scarcity, households either invest in water storage containers or dig boreholes. Others invest in bicycles, carts, and motorbikes to assist in fetching water from other sources like rivers or privately owned boreholes. This helps to reduce costs incurred when water is delivered by a tanker or water vendors who use carts to deliver water to homes in 20L (liters) or 30L jerry cans. The majority of households with piped water connections in Kenya have invested in water storage tanks with a capacity of between 100L, 200L, 1000L, and 1500L. The costs of the storage tank range between 300-60,000Kshs. The average cost of a build-up rainwater collection system with a capacity of more than 2.5m3 is approximately Kshs.9000. Digging a private well/ borehole costs approximately Kshs. 35,000 or Kshs 1000 per foot of depth. An average private well ranges between 20-35 feet (Amos, Rahman & Gathenya, 2016).

3.2.3 Water Treatment Costs

To ensure water is safe for drinking, it has to be treated to prevent water-borne diseases like Cholera, Typhoid, and diarrhea. Water is treated either through boiling, filtering, and the use of chlorine, water guard, or solar disinfection. Some treatment methods like filtration and distillation have very minimal financial costs while others like the use of water guard, boiling, and chlorination are associated with some costs. The use of water guards and boiling methods are for small-scale water treatment whereas chlorination is used in large-scale water treatment. Water boiling is associated with costs like fuel (firewood, gas, paraffin) or electricity.

Homes with piped water connections or privately owned boreholes incur fewer water costs as compared to those who travel for more than one kilometer to get water. Homes with higher income incur higher water coping costs than low-income earners. Big households have many needs for water since they live in Bungalows/Mansions while low-income earners live in small houses. They might only need basic needs like cooking and bathing while high-income earners use excess water especially in washrooms and general cleaning (Wanjama, 2010).

3.2.4 Water Harvesting

Water harvesting is the collection of rainwater. Water harvesting is a cheap and simple method for dealing with water scarcity. Rainwater harvesting is essential in areas where there are problems of environmental degradation, long dry seasons, and a high population increase. Arid and semi-arid areas usually experience drought where there are irregular rainfall and water is lost to the ground. In areas that are prone to drought, water harvesting is usually practiced through water pans and gutters. Water harvesting helps to conserve both water and soil. Several methods have been used for many years to harvest water for domestic use, agriculture, livestock, and industrial use. In Kenya, there is an increasing focus on water harvesting through the development projects by county government, Non-Governmental Organizations, state ministries, and other agencies as a decentralized solution to Kenya's water scarcity (Black et al. 2017).

A study by Mwaura, Koske, and Kiprotich (2017) revealed that benefits accrued from water harvesting are more than costs incurred in building or buying water collectors. The benefits include improving the value of livestock in the rural areas, saving time wasted while traveling to fetch water, or engaging water vendors, which could otherwise be used, in other income-generating activities. Besides, water harvesting saves water used in irrigation reducing the costs of agricultural activities to the farmers. The study also indicated that water harvesting successfully manages costs resulting from extreme weather conditions like drought. A long period of drought and floods are common in arid and semi-arid areas in Kenya. The most notable droughts were in 2001, 2003, 2006, 2009, and 2011 and major floods in 2006, 2010, and 2016.

3.3 Water Management

Through the Water Act 2002, the National Policy on Water Resources Management and Development gives the guidelines on how to manage water resources and provide water services countrywide. This act outlines the institutional and legal framework for managing and developing water resources and providing water services in Kenya (The Republic of Kenya, 2002). The management of water and water sources has been under the control of the government of Kenya until the private entities stepped into this water sector to provide water to the gated communities in the urban centers recently. Some households have boreholes to supply them water while others get the water from other private suppliers. According to the National Water Development report in 2006 by the government, the unsustainable land and water use policy has caused mismanagement of the water sources. In addition, ineffective laws and regulations placed by respective institutions, increasing water pollution, ineffective water allocation practices, and the degradation of water sources, water catmint areas, aquifers, and wetlands lead to water misuse and shortage in the country (Mutui, Omosa & Cun-Kuan, 2016).

Through the Water Act 2002, re-evaluation of the role of different actors in the sector and re-assignment of roles was carried out. Before the Water Act in 2002 was enacted, all water service provision was centralized and controlled by the National Water Conservation and Pipeline Corporation with the help of few entities, which were created in the year 1992. After the enactment, decentralization occurred allowing 91 local Water Service Providers (WSPs) to join the water sector. In Kenya, reforms have been carried out since 2002 to improve the management of water resources and increase access to water and sanitation services for both rural and urban populations.

There has been a wide set of implications on the water sector since the constitution was passed in 2010. The constitution acknowledges the need to access clean and safe water as a basic human right. It thus assigns the responsibility of supplying water and sanitation services to the 47 counties established in the country in their attempt to fulfill the importance of devolution in proper service provision to citizens. A new water act was enacted in 2016 that ensures that the water sector was more decentralized to include the water service provision in the 47 counties. The 47 waterworks development that was created were made to be part of the operationalization of the 2016 water act. The Ministry of Water and Irrigation under the National government remained with the mandate to create and develop the water policies. The 2016 water act was enacted to align the Water sector objectives with the constitution's devolution objective. It states that the functions in the water sector are both a responsibility of the county and national government hence they need to cooperate in ensuring citizens get water services. There is also a priority given to water use in domestic settings over that on irrigation and other uses.

The Water Act is in place to ensure the effective use and management of water resources. The Water Towers Conservation and Coordination Policy complements the Water Act by ensuring that there is adequate reception of water in the water towers for management under the Water Act.
Several institutions have been set up in pursuit of the act in accordance with the decentralizing of the water sector like the establishment of the Water Services Regulatory Board (WASREB). The main mandate of (WASREB) is to develop and enforce rules within the water sector to ensure access to efficient, sustainable, and affordable water services to Kenyan citizens. Water Sector Trust Fund (WSTF) also created under the act was restructured from Water Services Trust Fund. Its mandate is to finance water and sanitization service provision in the country. The institutions were established as an effort to

organize the water sector and fulfill the anticipated universal access to water in the country (Water Resources Management Authority, 2016).

A report by UNICEF (2015) shows a direct link between water management, human life, human health, the health of other plants and animals. Effective water management has a significant effect on the health of the population. This is due to contamination of drinking and bathing water, wastewater, solid waste, air pollution, etc. Because of this effect on health, Human capital is adversely affected.

3.3.1 SWOT Analysis of Water Resources Management in Kenya

Strengths • Kenya is home to great water towers in East Africa such as abundant rivers like Tana and forests like the Mau Forest (Ministry of Water, Irrigation and Sanitation, 2006). • Water Resources Management in Kenya possesses strong support from donors like the World Food Program and the World Bank (Belay, Semakula, Wambura & Jan 2010). • As a country that falls within the tropics, water resources are made available due to fair weather throughout the year accompanied by rains. • Possession of strong strategies and policy papers like National Water Resources Management Strategy and Water Policy Sessional Paper Number 1 of 1999. • Possession of transboundary water resources that are yet to the explored fully. For example, Kenya shares Lake Victoria with neighbors, Uganda, and Tanzania.	**Weaknesses** • Low levels of investment in pollution control • Low levels of investment in reducing the discharge of effluence from factories. • The high cost of connection of the urban residents to the metered water resource. • Lack of development of a real and sound financial system for water management and supply. • Poor water piping and sewerage location planning in the informal sector in Kenya(World Bank, 2015). • Inadequate provision of assessment resources, for instance, low assessment of the volume and speed of the rivers, data to monitor groundwater is also lowly collected, and fully operational river gauging stations have reduced.
Threats • Water catchment areas like Ewaso Ng'iro are degrading at a faster rate due to the addition of sediments. • Variable, Spatial, and Temporal Rainfall Patterns make it hard for water to reach some parts of the country (Ministry of Water, Irrigation and Sanitation, 2013). • Increase in the salinization of the water resources • Infiltration of cartels and bureaucracy in water resource management	**Opportunities** • Implementation of the Water Reform Strategies to tackle the challenges. • Opportunity to increase collaboration with local and international partners to better manage water resources (Belay, Semakula, Wambura & Jan 2010). • Building broad-based stakeholder involvement and creation of transparency in the use of funds as a way of attracting more donor support. • Opportunity to take advantage of the increase in population and irrigation

• Lack of modern storage equipment, a threat to the harvesting and storage of water during flooding.	demand to make more water resources available to residents and conserve water catchment. • Opportunity to continue raising awareness of water catchment among communities and encourage tree planting.

3.3.2 Water Resources In Kenya In Comparison With Other Eastern Africa Countries

In comparison with neighboring countries, it's clear Kenya has the lowest water resource per capita. As indicated below, South Sudan has the highest water resources per capita while Tanzania has the highest water precipitation in volume. Kenya and Somalia have water resources per capita lower than 1000m^3 making them water-scarce countries. On the other hand, Uganda, Tanzania, Rwanda, Ethiopia, Burundi, and Eritrea have water resources per capita between 1000-2000 qualifying them as countries facing water stress conditions. Water dependency indicates the percentage of water that comes into the country from other countries (Transboundary waters). Kenya has 33% water dependency from other countries, Eritrea has the highest (62%) water from other countries while Ethiopia recorded 0% of the water from other countries.

Table 3: Water Availability and Water Use

Countries	**Renewable Water Resources (billion m^3/year)**	**Water Resources per Capita (m^3/person/year)**	**Water Precipitation In Volume (billion m^3/year)**	**Water Dependency (Water from outside the country)**
Kenya	31	617.7	365.6	33%
Uganda	60	1,402	285.0	35%
Tanzania	96.3	1,680	1,015.0	13%
Rwanda	13	1,089	31.9	29%
Ethiopia	122	1,162	936.4	0%
South Sudan	50	3,936	579.9	66%
Burundi	13	1,154	35.5	20%
Somali	15	997	179.8	59%
Eritrea	7	1,443	45.2	62%

Source: *Water use statistics*. (n.d.). Worldometer - real-time world statistics. https://www.worldometers.info/water/ (2017)

3.4 Challenges Facing Water Management in Kenya

The water management sector has faced challenges for many years in Kenya. Among the challenges is the perception that the government should provide water to all its citizens free. This led to an unwillingness to pay water bills which contributes to increasing water hawkers in Kenya. This becomes unviable for water institutions in Kenya because of the lack of enough revenue from water provision in the country. Water scarcity is more prevalent in rural areas and to a very great extent in Arid and Semi-Arid Areas. The conflict that arises in water sources also challenges water management in Kenya. For instance, there are frequent conflicts between competing upstream (irrigation and hydropower) and downstream (irrigation and livestock watering) the Tana River Basin.
According to (Chepyegon, C., & Kamiya, D. 2018), it is evident that about 42% of the water in the country is accounted for by Non-Revenue Water (NRW). The rural areas, arid and semi-arid areas are the areas in Kenya that are quite facing water shortages which is a challenge to the female gender who are given the role of fetching water for domestic use. Climate change has contributed to water shortages in many parts of the country and the situation is not getting any better. The supply of piped water in the rural areas is a great challenge and this affects irrigation and agri-business.

The budget allocation for the water sector in Kenya is indicated below the amount needed to satisfy the increasing water demand. 2.8% of the national budget is allocated to the sector is which is approximately 44% of the required cost of investment (UNICEF-KENYA, 2019). The availability of funds determines the extent to which capital investments can be made and conducting needs baseline surveys. Additionally, managers, ability to source funds through customers' water bills makes planning decisions very hard. Failure to involve the community before making any development like piping through people’s compounds leads to top-down policies which in most cases do not help in solving people’s real problems.

Poverty problems are usually linked to water challenges. Introducing rainwater harvesting improves water availability, its closeness, its quantity, and its quality. However, due to poverty, many people in rural areas and urban settlements cannot afford to buy water storage facilities like tanks and they only use available household resources to harvest rainwater.
The management of the rural water supplies has been left under the Community Based Organizations mandate due to unfavorable conditions to enhance commercialization of the water management sector. The CBO members do not have adequate management skills to manage these facilities effectively hence leading to water misallocation and misuse.

4. CONCLUSION

Kenya is a water-scarce country and the high population increase has worsened the situation. Population increases cause high demand for water exerting more pressure on natural water sources like rivers, swamps, natural dams, and lakes which are diminishing at a very high rate. Only a small percentage of the whole population has access to drink water. This is due to high water costs, inadequate and unreliable rainfall, poor water management, and a lack of water conservation skills. The most common source of drinking water in town centers is piped water

into the residents, dwelling place/plot/flat while surface water is the main source of water for rural residents followed by piped water into the homes.
In Kenya, the cost of connecting water through the pipes is very high at $400 which is beyond the reach of many households especially in the rural areas and urban settlements. A household without access to piped water from the public water companies either buys water from tankers, boreholes, or bottled water from water supermarkets and shops. Homes with piped water connections or privately owned boreholes incur fewer water costs as compared to those who travel for more than one kilometer to get water. Homes with higher income incur higher water coping costs than low-income earners which makes it even hard for low-class people to access clean water. In the Arid and Semi-Arid Areas, water harvesting is usually practiced through water pans and gutters. Benefits accrued from water harvesting are more than expenses of building or buying water collectors.

Under the Water Act National Policy on Water Resource Management and Development established the Water Services Regulatory Board to oversee the management of water resources provision of water services in Kenya. However, water management faces challenges, which include the perception that the government should provide water to all its citizens for free which has created unwillingness to pay water bills leading to cutoffs for piped water. The budget allocated to the water sector in Kenya is inadequate to satisfy the ever-increasing water demand since the availability of funds determines the extent to which capital investments can be made and conducting needs baseline surveys. The water situation in Kenya, therefore, calls for suitable management of the water sector in Kenya to ensure that majority of Kenyan citizens if not all can access clean water for drinking, domestic, and livestock use.

5. RECOMMENDATIONS

Climate change and its unpredictability continues to have a negative effect on the availability of water sources. There are uncertainties created by the current projections on climate change regarding the availability of water sources. According to Sustainable Development Goal 6, all stakeholders have to implement integrated water resources management practices appropriately at all levels, including transboundary cooperation. Competent managers should be hired to oversee the management, protection, and preservation of the water resources for future generations.

The water demand is very high in Kenya while its distribution to the users is diminishing. There is a need to increase the availability of water by supporting the construction of sustainable water sources like boreholes and protecting springs and rivers. The community should be encouraged to make more investments in rainwater harvesting to increase access to safe water and also reduce water costs since borehole, springs, and river water is not billed. The government should also reinforce laws and regulations aimed at the protection of water resources and water catchment areas.

To curb some challenges that impede access to safe household water supply, safe water sources close to homesteads at least 200 meters should be located and exploited. This might help to decrease health issues like cholera and typhoid and also increase water consumption as well as alleviate poverty levels. People should be empowered to start income-generating activities in

rural areas to help them raise money to pay water bills for safe water. Water coverage in rural areas should also be increased through investments in water storage facilities that can be used by many people. There has been a mere 4% increase in water coverage within the past five years. To achieve the target in vision 2030, the water sector needs to grow at least by 4% per year that is thrice the current rate. In many towns in Kenya, water demand is higher than its production leading to water rationing.

The key challenge is ensuring that all water projects are successful to achieve the intended goals. However, many water projects in the communities especially the boreholes in areas where there are no pipe connections are not successful. This is mainly because stakeholders who are only focused on construction costs drive the project. They, therefore, end up overseeing the construction of substandard projects that cannot sustain the entire community. Therefore, investments in infrastructure should be increased to ensure more water projects are established in areas that frequently face water challenges.
The financial sector's sustainability is facing a threat from water losses. Funds that could increase access to and improve water and sanitization services are wasted. According to the 42% Non-Revenue Water levels and the Ksh.20.67 billion billing, the total loss in 2016 and 2017 is estimated as Ksh.7.8 billion while the acceptable losses are at 20%. The customer should thus control the use of non-Revenue Water since it contradicts the country's aspiration to enhance standards of living by being the direct expense.

Many utilities continue to operate on the non-cost reflective tariffs even though they are underperforming. This has continued to be a setback in the desire for full-cost recovery since the tariffs do not cover the cost. Currently, to cover the inefficiency of the system and the inability of the tariffs to cover the cost, an additional Ksh.27 should be either subsidized to the water supplier or added to the customer's bill. It has forced the utility managers to explain the situation to the authorities in the country to help them understand the need to enhance cost recovery tariffs and the deterioration of services resulting from the persisting investment gap existing in the water sector. The players in the water sector are also encouraged to explore models that are efficient to provide services to their customers like the utilization of the economies of scale to enhance efficiency in water sector service delivery.

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SOME METHODS OF WATER CONSERVATION IN AGRICULTURE WHICH MAY ALSO BE INTEGRATED TO ACHIEVE HIGHER PRODUCTIVITY AND QUALITY ECOLOGICALLY

III. Some Beneficial Practices and Their Prospective and Additive Potentials

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Abstract

As it is very well known, and mentioned in the previous articles of the present author, vast majority of billions of plant propagators have limited power of interference and control of the complex factors affecting crop productivity at natural conditions, especially under the pressure of cost-profit ratio and environmental concerns at the global warming era.

Here it will be attempted to review some locally proven promising performances of some practices and their potentials in terms of productivity and water use efficiency (WUE) within the framework of sustainable agriculture at changing climatic and environmental conditions. The aim here is attracting attention to the higher potential of integrating some of them for higher water economy and productivity.

Considering t**he considerable differences in popularity of practices in different countries, regions, academical and practice oriented literature showing the time lost for the reflection of academic advancements to practice, or neglecting them for some reasons in spite of the tremendously increased worldwide communication possibilities, it will be attempted to attract attention to the possible benefits of using meta-analytical approaches to the challenging complicated problems related with global warming stimulated climate changes.**

Keywords: Plant physiology, global warming, ecological agriculture, water economy

Introduction

Feller & Vaseva (2014) reviewed the literature on the impacts of drought and high temperature on physiological processes in agronomically important plants, considering the predictions made by climate models for the present and the next decades, which were indicating more frequent and more severe extreme events, such as heat waves, severe and extended drought periods, and flooding in many regions. Actually, as known well and also recently reported by Kim, Iizumi & Nishimori (2019), such impacts of global warming started to affect agricultural production in many regions in earlier decades. The relationship of global warming and increase in wildfires at the termination of ice age has long been known, as Pyne (2020) described as "From Pleistocene to Pyrocene: Fire Replaces Ice" in the title of his article on the history of anthropogenic wildfires.

National Drought Mitigation Center (NDMC) of U.S., which is recently operating at University of Nebraska, issued a text titled "Why Plan For Drought?" (NDMC, 2021), providing justification for the necessity of a plan as avoiding unpleasant surprises and enjoy the benefits of normal or rainy years. They reminded that the center had been commissioned the artwork in the late 1990s to show how drought, as a slow-moving natural disaster, tending to emerge and intensify. It is added that The Federal Emergency Management Agency (FEMA) had estimated in 1995 that drought was costing the U. S. an average of $6 to 8 billion a year. The NDMC had assembled a list of "Billion Dollar Weather Disasters" since 1980, and the 90 incidents listed till 2008, 14 of them were drought and wildfire. Drought in 1980, for instance costed $55.4 billion loss, caused about 10,000 heat-related deaths; in 1988, the loss was $71.2 billion with about 7,500 heat-related deaths. It was said that FEMA was calculating the benefits of mitigation, taking precautinary steps to prevent known impacts from a natural disaster was saving $4 for every $1 expended, which is clearly more efficient and effective than taking measures in crisis mode. It was added that after-the-fact assistance to farmers was expensive and might not reach to the right people. Ultimately, costs were spread more widely to other parts of the food system, taxpayers and consumers; in developing countries, droghts were leading to social and economical problems. Growing populations in areas that were dependent on regular rains, were contributing to vulnerability to drought. Plans that were prepared in wet years, decades might be built in part on unrealistic expectations of water supply. As urban water supplies in some areas were strained, recognition of the need to balance environmental, urban, agricultural water use, protection of fish stocks and aqueous wildlife were increasing.

NDMC drew attention to the need of conducting drought planning at all levels of decision-making authorities over water, agriculture, environment and natural resources, health, water suppliers and municipalities. Farmers, ranchers, and others whose livelihoods depending on regular rain should also know their options and have plans. It was also added that people were tending to forget about it and to resume business as usual, although climatology was evidenting that drought would happen again. It is worth to add once more here that global warming is known to increase the frequency and intensity of the climatic incidents (NASEM, 2019), which are more challenging than commonly assumed. Even the title of final chapter of the publication by IPCC (2018), "Adaptation Complex Interactions among Climate Events, Exposure, and Vulnerability"stressed the level of complications involved.

Discussion

In accordance with the complexity of the issue, Feller et al. (2014) focussed on drought and heat effects on physiological status and productivity of agronomically important plants in their review article, considering the growing food security issues. They drew attention to importance of stomatal opening in the regulatory mechanisms during drought and heat stress, simultaneously influencing water loss via transpiration and CO_2 diffusion into the leaf apoplast. They added that along with the reversible short-term control of stomatal opening, stomata and leaf epidermis might produce waxy deposits and irreversibly down-regulate the stomatal conductance and non-stomatal transpiration and photosynthesis at the leaves under stress. Actually, the effect of transpiration on cooling leaves can be added to the influences mentioned by them. Consequently, they said, heat sensitive key enzyme of Calvin cycle, Rubiscoactivase might become another limiting factor to the accumulation of reactive oxygen species (ROS). Drought and heat were causing accumulation of free amino acids, which were partially converted into compatible solutes such as proline, while rates of both nitrate reduction and *denovo* amino acid biosynthesis were decreasing. Another key parameter in regulation of water economy can be added to stomatal control is obviously the efficiency of the root system, as Zhang, Shan & Deng (2002) stressed for wheat, in regard to evolution of wheat from 2n to 6n.

Zhang et al. (2002) considered the physiological basis of raising crop water use efficiency (WUE), and cleverly designed their field experiments to investigate the change of wheat WUE at whole plant level, covering root system growth in evolution by using 10 wheat evolution genotypes with different ploidy chromosomes sets. They reported the results which were showing that evolution from diploid (2n), to allohexaploid (6n) increased WUE at whole plant level; but root system growth in terms of root weight, total length and root/shoot ratio decreased with the increase of ploidy under dry and irrigated conditions. The negative correlation of WUE with root weight and root/shoot ratio of wheat in evolution was found at significant level. Root system growth has an adverse redundancy for WUE in wheat evolution, and the root redundancy reduced with the increase of ploidy chromosomes, which resulted in the increase of wheat WUE at whole plant level.

Considering the results of the studies by Zhang at al and by Feller et al mentioned above, which were showing the increase in protective proteins like dehydrins, chaperones, antioxidant and proline biosynthetic enzymes in leaves and the effects on the effects on long-distance translocation of solutes via xylem and phloem, and also leaf senescence development, it can be concluded that all of those factors were relevant for the overall performance of crops under drought and heat stress. Thus, they should be considered for genotype selection and breeding programs, as the susceptibility to abiotic stresses might differ considerably among species or varieties of a crop, which was particularly important for the annual crops. The literature referred by them were showing the significance of stress period for the crop productivity, which was not ruling the fact out that subsequent recovery stages were equally crucial for a proper evaluation of the overall performance.

Feller et al. added that progression and duration of stress, plant developmental stage and other biotic and abiotic factors might be influencing the stress response. Certain species that were affected at early developmental stage, and could recover, survive; others could cope with the conditions at the beginning and remain quite productive, but their surviving potential could be exhausted and irreversibly damaged. Considering the need for a comprehensive evaluation of plant stress response including the overall characterization of plant physiological behavior and survival, they summarized some of the major physiological parameters characterizing stress response reactions which could be implemented as tools for evaluation of stress effects. They added that the impact of drought and heat on physiological status and productivity of agronomically important plants would become even more relevant during the following decades of global warming era. Assimilatory processes, long-distance translocation of solutes via xylem and phloem, changes in protein patterns and free amino acids, as well as the physiological phenomena associated with induced leaf senescence were addressed in their article.

The comments of Feller et al. on the relations of developmental stage and stress response, flower abortion and premature fruit abscission can be added to the effects they mentioned, as Chandra, Roychoudhury (2020) did so in their chapter titled "Penconazole, Paclobutrazol, and Triacontanol substances in Overcoming Environmental Stress in Plants"which was the 26th chapter of in the very comprehensive and excellent book on "Protective Chemical Agents in the Amelioration of Plant Abiotic Stress" edited by Roychoudhury & Tripathi (2020).In their chapter Chandra et al stressed the importance of the recent achievement of increasing yield by use of chemicals in agriculture. They focussed on triazolic fungicides, Penconazole (PCZ), paclobutrazol (PBZ) and triacontanol (TCN) natural plant growth hormone and regulator (PGR), adding that those chemicals had been widely exploited in agriculture to manipulate crop production and evading abiotic stress, as the agents directly stimulating growth hormones, capable of promoting growth also in adverse environmental conditions.

Chandra et al added that PCZ had been reported for its role in reducing undesirable effects of drought by reducing membrane damage and overcoming salt stress, decreasing also the level of ROSs, enhancing antioxidant potential, and promoting root growth. Likewise, exogenous application of TCN was stimulating production of free amino acids, enzyme activities, and ratio of L (+) and D (−) adenosine, which were known as the factors improving quality and quantity of agricultural crops. Despite the presence of numerous reports showing that application of PBZ was regulating vegetative growth and increasing fruiting, flowering and the yield in many crops, its antagonistic effect on gibberellin biosynthesis and many physiological changes such as rising photosynthetic pigments, nutrient assimilation, delaying aging process, increasing flowering, they said, only few articles were available on the molecular and biochemical aspects of its efficiency. Their comment on the weak interest in some aspects of beneficial effects of some findings and applications is another example supporting the idea expressed in the title of the present series of articles, and described in the previous ones (Duygu, 2020 &2021).

Zaid, Asgher, Wani et al. (2020) reviewed the literature in their brilliant article on role of TCN (Tria, TRIA) hormone in overcoming environmental stresses in the same book edited by Roychoudhury et al. (2020). The book covered chapters on the roles of many chemicals, metabolites, growth regulators and phytohormones: Ca, K, S, Fe, Zn, Cu, Se, Mn, thiourea, H_2O_2, NO, H_2S, proline and glycine, etaine; melatonin, glutathione, sodium nitroprusside, sugars, sugar polyols, ascorbate, tocopherols, oxylipins and strobilurins, isoprenoids, abscisic acid (ABA), polyamines, brassinosteroids, jasmonic acid (JA) and jasmonates, strigolactones, salicylic acid (SA), γ-aminobutyric acid and nanoparticles.

Zaid, et al. (2020) listed some environmental stresses such as metal/metalloid toxicity, salt, ultraviolet-B, temperature, water and anthropogenic stresses such as machine-induced transplantation shock as the most extreme limiting factors to sustainable and productive agricultural practices. They considered them as intricate factors, occuring in individually and/or combination, which were inducing various detrimental impacts on physiological/biochemical and molecular processes of plants, and eventually causing abnormalities in growth, development, and overall yield.

After stressing the role of phytohormones in regulating growth and sustainable amelioration of abiotic stress-induced undesirable effects in plants, Zaid et al. focussed on the role of Tria hormone in improving abiotic stress tolerance in plants through regulation of main metabolic processes. They added that the fundamental mechanisms of Tria-mediated tolerance to major environmental stresses remained less explored in plants. After briefly highlighting the literature on historical background of Tria in plants, they focussed on the role of the hormone during major environmental stresses in plants, and discussed potentiality of foliar and priming applications in imparting abiotic stress tolerance in plants. The mechanisms of this signaling molecule in boosting growth in agriculture and allied sectors by behaving as an alleviation agent under various environmental pressures were also covered. In accordance with their approach to the hormone, there were only two chemical factors mentioned twice in the titles of the chapters of the book by Roychoudhury &, Tripathi (2020), as the chemicals involved in increasing crop abiotic stress tolerance: sugars and TRIA hormone.

Since Ries & Wert reported in 1977, the application of this 30-carbon primary alcohol to rice (*Oryza sativa* L.) seedlings in nutrient culture solutions at 2.3 ×10(-8) M (10 μg/l) level caused an increase in fresh and dry weight in addition to leaf area of the whole plants as early as 3rd h of treatment even at relatively low light intensities or in the dark, where control plants lost dry weight, the hormone attracted attention of scientists. The dry weight gain in the dark unless CO_2 was removed from the atmosphere, and 30% increment in Kjeldahl-N per plant over controls after keeping them in the dark for 6 h. were the results deserving attention. Ries, Wert, Sweeley et al. (1977) also reported that alfalfa meal and its chloroform extracts increased the growth and yield of several plant species; they also succeeded to isolate a crystalline substance from the active fraction of the meal, which increased the dry weight and water uptake of rice seedlings when sprayed on the foliage or applied in nutrient culture. The substance was identified as Tria by mass spectrometry by them, and the effects of its sprays were also experimentally shown to increase the growth of corn, barley and tomatoes grown in soil, and rice grown in nutrient cultures over a wide range of concentrations.

Similar results for 4-day-old hydroponically grown leaf lettuce (*Lactuca sativa* L.) seedlings in a controlled environment by Knight & Mitchell (1987): leaf fresh and dry weight increased 13% to 20%, root fresh and dry weight increased 13% to 24% 6 days after $10^{(-7)}$ M application of relative to plants sprayed with water. Interesting to note here that, there was no benefit of repeating application on leaf dry weight. In their excellent paper on the total nitrogen increases and changes in its fractions in rice and corn plants following applications of TRIA, Knowles & Ries (1981) reported that the hormone increased total reducible nitrogen (total N) of rice seedlings within 40 minutes besides the increases in fresh and dry weight values. They added that increases in total N in the supernatants from homogenates of corn (*Zea mays* L.) and rice leaves treated with TRIA only for one minute before grinding had occurred within 30 and 80 minutes, respectively. Their further investigation of the source of the increase by using ^{15}N isotope enrichment and depletion studies showed that it was the result of utilization of atmospheric substitution. They observed that the increase in total N in the seedlings was independent of the method of N analysis and the present level of nitrate in them; TRIA was not altering the nitrate uptake or its endogenous levels in corn and rice seedlings studied, but increased the soluble N pools, specifically the free amino acid and soluble protein fractions, that might be stimulating an effective change in the chemical composition of the seedlings.

Ries& Wert (1988) applied TRIA to shoots or roots of rice (*Oryza sativa* L.) seedlings and measured increases in the dry weight, and analyzed alterations in the metabolism within 10 min of application in order to understand the physiological mechanism of the hormone. They observed the loss of metabolic activity by application of octacosanol, C28 primary fatty alcohol (OCTA) with TRIA on the roots or shoots, when OCTA was applied on the opposite part of the seedling at least 1 min before TRIA application. They decided that TRIA was rapidly eliciting second Messengers, which were translocated rapidly throughout the plant. The apparent result was stimulation of growth and water uptake. They named the second messengers as TRIM and OCTAM, and succeeded to extract water-soluble TRIM from the plants treated with TRIA, which was increasing the growth of rice seedlings about 50% more than the extracts obtained from untreated plants within 24 h of application. They showed that both OCTAM and OCTA were inhibiting the activity of TRIA but not of TRIM; the TRIA messenger was isolated from rice roots within 1 min of a foliar application of TRIA. The TRIM elicited by TRIA was passing through a 4-mm column of water connecting cut rice shoots with their roots and could also be recovered from the water in which cut stems of TRIA-treated plants had been immersed. The clever study of Ries et al. (1988) revealed that TRIA applications to oat (*Avena sativa* L.) or tomato (*Lycopersicon esculentum* Mill.) shoots, which were connected to rice roots by a 4-mm water column also had TRIM in rice roots.

Ries, S. (1991) attracted attention to the fact that TRIA, which was used to increase crop yields on millions of hectares, particularly in Asia to affect photosynthesis, nutrient uptake, and enzyme activities, its initial site of action was still needed to be elucidated. He added that the TRIA messenger TRIM was identified as 9-beta-l(+)-adenosine (9H-purin-6-amine, 9-beta-l-ribofuranosyl) enantiomer, which had not been reported as a natural compound previously, was making about 1% of the total adenosine pool up in roots from untreated rice seedlings. It took a decade to reveal the molecular genetical mechanism of the TRIA by isolating the genes of rice regulated by the hormone; Chen, Yuan, Chen, et al. (2002) succeeded to characterize them by using the cDNA library

Chen et al. (2002) also showed that while dry weight, protein and chlorophyll contents of rice seedlings were increasing after foliar application of TRIA, there was a very quick increase in the leaf net photosynthesis rate (Pn), and this increase was persistent at a given photon flux density (PFD, mean number of photons per leaf area). They also succeeded to isolate all of the TRIA-regulated genes from cDNA library by differential screening with probes generated from the forward-and reverse-suppression subtractive hybridization (SSH) populations, and confirmed their results by Northern blot. Their sequence analysis revealed that most of the up-regulated genes were involved in encoding the photosynthetic and photorespiratory proteins. Two down-regulated genes were encoding an Abscisic acid (ABA) inhibitor and also a stress, wounding related protein. They interpreted the results obtained as evidences of up-regulation of the photosynthesis and suppression of stresses in rice plants. Time-course profiles of expression of rbcS isogenes (Clone names of Tria-Regulated Genes in Rice) lead them to suggest that promotive effect of TRIA on regulation of photosynthesis was organized by some complex mechanisms. Sperotto, Ricachenevsky, Duarte et al. (2009), as a matter of fact, identified up-regulated genes in flag leaves during rice grain filling stage and characterized a new plant growth inhibitor named OsNAC5, which was an ABA dependent transcription factor.

Considering that the main sources of insufficient levels of micronutrients such as Fe and Zn were the flag leaves in rice seedlings, Sperotto, et al. (2009) studied on the molecular mechanisms regulating metal mobilization from leaves to developing seeds by analyzing suppression subtractive hybridization in flag leaves of two rice cv.s. They succeeded to isolate 78 up-regulated sequences in flag leaves at the grain filling stage, relative to the ones present at panicle exertion stage. They confirmed differential expression of selected genes, which were encoding seven transport proteins, the OsNAS3 enzyme and the OsNAC5 transcription factor by quantitative reverse transcription polymerase chain reaction (RT-PCR) technique, which could combine reverse transcription of RNA into complemantary DNA (cDNA) for amplification of specific DNA targets using polymerase chain reaction. They also succeeded to show that OsNAC5 expression was up-regulated by natural aging and induced senescence processes by different factors, such as dark, ABA application, high salinity, cold and Fe-deficiency. They added that the expression was not affected in the presence of 6-benzylaminopurine (BAP) cytokinin senescence inhibitor under dark-induced senescence. Abolishment of salt induction of OsNAC5 expression by the ABA inhibitor nicotinamide and the presence of cis-acting elements in the promoter region of the OsNAC5 gene lead the researchers to conclude that regulation was controlled by ABA. By using four different rice cultivars, Sperotto, et al. also evidented that up-regulation of OsNAC5 was starting earlier and reaching to higher levels in flag leaves and panicles of IR75862 plants, which were containing higher Fe, Zn and protein concentrations in their seeds. They concluded that OsNAC5 was a novel senescence-associated ABA-dependent NAC transcription factor, which appeared to take part in remobilization of Fe, Zn and amino acids from green tissues to seeds. As known transcription factors are important switches of transcription networks, and NAC group are plant specific one taking part in some important processes, such as development, abiotic and biotic stresses.

Taking the important contribution of soil salinity as a major abiotic stresses to crop yield losses worldwide into consideration, Karam & Keramat (2017) studied the effect of exogenous foliar spray of TRIA on coriander (*Coriamdrum sativum* L.) under salt stress. After briefly reviewing the effects of abiotic stresses, such as induction of overproduction of ROS, damages of DNA, proteins, chlorophyll, and also cellular membranes by inducing lipid peroxidation in terms of malondialdehyde (MDA) content in leaves, they added that plant antioxidative system response was comprising several enzymes, such as superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), and peroxidase (POX) and non-enzymatic low molecular weight antioxidants, such as ascorbic acid (AsA), α-tocopherol, carotenoids and reduced glutathione (GSH), they presented their own findings. Karam et al. (2017) showed that salinity stress was causing a few morphological and physiological changes in coriander, including decrease in root and shoot dry weight, increased H_2O_2 content and lipid peroxidation. Foliar spray of 10μM TRIA was found effective in reducing the adverse effects of salt stress through modulating activities of antioxidant enzymes. They referred to the earlier studies evidenting that endogenous levels of phyto-hormones were undergoing considerable changes under salt stress, including the decreases in the levels of most of growth regulators in the plants exposed to salinity stress, they could, however, recover by the exogenous hormone applications. They also referred to the literature showing that various physiological and biochemical processes could be regulated by foliar application of TRIA under salinity stress. Growth and yield of various crop species could be increased at their various growth stages, by enhancing activities of some key enzymes, modulating photosynthesis, photorespiration, chlorophyll synthesis, cell division, and uptake of water and mineral nutrients.

Recently, Islam and Mohammed (2020) reviewed the literature on the role of TRIA as a dynamic PGR under diverse environmental conditions. Like Zaid, et al. (2020) did so, they referred to the studies showing the well defined roles of ABA, auxin, brassinosteroids, cytokinins, ethylene, gibberellins, jasmonates, NO, SA and strigolactones in plants very briefly, and attracted attention to numerous studies showing that the mode of the hormone actions were varying under stress conditions. After this short introduction they focussed on TRIA, which was first identified in the hay of alfalfa in 1997, and referred to studies reporting that it was found also in epicuticular waxes of diverse plant species, such as *Croton californicus*, *Copernica cerifera*, *Medicago sativa*, *Jatropha curcas*, *Oryza sativa*, *Vaccinium ashei,* and some others which have been reported by different researchers, such as green tea leaves, tea waste, rice bran economically [Sontakke, Nagavekar, Kumari et al (2018), Central Food Technological Research Institute] and also some of who are referrals in the present article.

As known very well, C and N metabolisms are interrelated, and Nitrate reductase (NR) is essential for nitrogen metabolism as the initiator of NO_3 assimilation (Foyer, Ferrario-Méry, & Noctor, 2001). On the role of foliar application of TRIA on NR activity Islam et al. concluded that an increase might be responsible for the enhancement of photosynthetic rate and increase in biomass and productivity. They referred to studies showing that 3 to 5 times foliar spray treatments of 1 μM or 10^{-6} M TRIA could increase NR activity against controls, within a range of 27.6 to 44.6% in various crops,. In accordance with the interrelated metabolitic activities affected by TRIA applications, Foyer et al. also reviewed the literature on the noticable effects on leaf nitrogen (N), phosphorus (P) and potassium (K) contents in most of the economically important crops, and referred to reports evidenting the significant increments in leaf N, P and K contents of various crops compared to control groups. As it would be expected, they added that TRIA was also improving the content and yield of most of the economically important harvests, and referred to a number of studies showing several times spray treatments of Vipul™ formulation containing 0.1% TRIA to the foliage of tomato, *Lycopersicum esculentum* Mill. increased yield attributes such as bud formation, number of fruits and their weight, diameter and total yields per plant of than control groups. Similar beneficial effects on yield and yield attributes, such as improved flowering, quality of flowers, fruit set and reduced flower drop and similar parameters of *Avena sativa* L., *Malus domistica* Borkh., *Medicago sativa* L., *Olea europaea* L., *Zingiber officinale* Rosc., *Cymbopogon flexuosus* L., *Curcuma longa* L., *Withania somniferum* L., and *Datura innoxi* Mill., *Lablab purpureus* L., and *Senna occidentalis* L., *Punica granatum* L. were also covered. It is worthmentioning the significant increases in *Solanum lycopersicum* L. attributes here as an example: in terms of weight, number and yield of fruits per plant over the controls were presented as 35.4%, 38.0%, and 57.6% respectively. In another referral study it was shown that application of 0.35 g a.i/ha (gr.s of active ingredient per ha.) TRIA enhanced seed yield and harvest index (wgt of grain per total wgt of above ground biomass) in *Medicago sativa* L. over the controls considerably. It is worthmentioning here that TRIA has also been known as the natural constituent of insect waxes for some time [Irmak, Dunford, & Milligan (2006); Ma, Ma, Zhang, et al. (2018)] As mentioned by Irmak et al. policosanol (PC) was a mixture of high molecular weight aliphatic primary alcohols, and a number of commercial dietary supplements containing PC available in the USA were mostly prepared from beeswax or sugar cane extracts. They compared the PC contents and compositions of beeswax, sugar cane and wheat as the sources, and analyzed compositions of several commercial supplements. They found that wheat germ oil (WGO) contained the highest total PC (628 mg/kg) among the wheat extracts and milling products examined; total PC contents of wheat straw (164 mg/kg) and sugar cane peel (270 mg/kg) were of the same order of magnitude. The total PC contents of brown beeswax were about 20 and 45 times higher than those of the WGO-solids and sugar cane peel, respectively. The PC compositions of the samples analyzed found to vary significantly with the source, and wheat was chosen as the material which could be a viable PC source for further product developments.

Ma et al. (2018) focused on insect wax, considering its role in economic wax production in China and its value as a good source of PC, they took it as a candidate supplement in foodstuff and pharmaceuticals that had important physiological activities. They aimed to investigate a high-yield and rapid method for PC fabrication from insect wax, and reported their success in developing a method that increased the yield of PC to 83.20%, four times greater than that of other methods that were in use. Ma, et al added that hexacosanol, octacosanol and TRIA were the main policosanols of interest, due to their significant physiological activities, and presented their contents as 6% to 7%, 42% to 46%, 27% to 28%, and 5% to 6%, respectively. The point ought to be stressed here is the distribution of TRIA in a *wide range of taxa*. When it comes to the hormonal effects of its applications, an accelerating *growth* of *scientific literature on the subject can be attributed to the outstanding beneficial performance as a GR on a wide range of living organisms. There are also studies showing its therapeutic uses and improving pharmacologically active chemical synthesis in medicinal plants [*Khan, Bhardwaj, Naeem, et al. (2009); Naeem, Ansari, Alam, et al.(2019)], and also therapoetic uses (Wang, Yu, Wang et al. 2020), including its potential as an antitumor agent (Wang, Fan, Zhu, et al. 2014).

Islam et al (2020) referred to the vast literature on the positive effects of relatively low concentrations of exogenous TRIA applications to different crops, covering enhancement of plant biomass, photosynthetic pigments, gas exchange parameters, mineral nutrient acquisition, leaf carbonic anhydrase (CA), nitrate reductase (NR) activities, accumulation of osmolytes, modulation of antioxidant enzyme activities, yield and quality attributes, changes in stem and leaf anatomy including vascular tissue systems. They also covered the literature on suppression or enhancement of the stress responses by regulating the gene expression, its essential roles in responses to abiotic stresses such as acid mist, heat, chilling, drought, heavy metal and salt stress, amelioration of the toxic effects by increasing plant biomass, chlorophyll, gas exchange parameters, quantum efficiency, mineral nutrient acquisition, compatible solutes accumulation, enzymatic and non-enzymatic antioxidant defense system. Due to diverse roles of the hormone, they focussed on modulation of plant growth and development under normal and abiotic stress conditions, its relation with other phytohormones and its effects on L(+)-adenosine formation. They drew attention also to its indirect effects, such as activation of calmodulin protein and probably taking part in direct modulation of transcription factors via Calmodulin-binding transcription activators (CAMTAs). They added that its actuation of the activities of kinases and phosphatases was leading to expressions of photosynthetic and photosynthesis associated genes; TRIA might also regulate stress-mitigating genes, modulate antioxidant defense systems and increase osmolytes accumulation leading to growth and development enhancement at normal and stress conditions.

The beneficial effects of TRIA on various metabolic processes occurring at seed germination, seedling growth and development stages, stimulation of photosynthesis and enzyme activities, its pivotal role in inducing/establishing resistance against various abiotic stresses by regulating gene expression, and also triggering its secondary messengers have also been reviewed by Islam et al. in their outstanding article. They attracted attention to the presence of non-racemic adenosine in TRIA treated plants, which was stimulating the beneficial plant processes, whereas racemic form could not. As a matter of fact, the exogenous application of L(+)-adenosine was also stimulating plant physio-biochemical processes, affecting morpho-physiology and biochemistry of crop plants under normal conditions. They summarized the beneficial effects of the hormone in eleven roles from increasing root system length and fresh/dry mass, to Malondialdehyde (MDA)/H2O2 reduction, which was the sign of decreased damage by ROS, and finally to increased mineral nutrition, osmolyte accumulation, growth and yield.

The importance of high number of studies reporting the essential role of the hormone in regulating a broad spectrum of plant morphological responses in most of the harvests, such as Solanum lycopersicum L., Zingiber officinale Rosc. and Curcuma longa L. so forth, was emphasized by Islam et al. They referred to interesting results of some studies, such as the ones reporting enhancement of fresh and dry weight of shoot and root of S. lycopersicum, P. somniferum L. by twice foliar spray of TRIA up to 1 ppm concentration, a number of studies presenting similar results on a wide range of crops, enhancement of the physio-biochemical attributes of vegetables, oilseeds, medicinal, aromatic, ornamental and horticultural ones. The referral studies were the ones reporting beneficial increases in many parameters over the control groups: chlorophyll and carotenoids, net photosynthetic rate (PN), internal CO2 concentration (Ci), stomatal conductance (gs), size and number of the chloroplasts, carotenoids and total chlorophyll or chlorophyll a, b, a + b, ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) and rbcS gene activities, and gas exchange attributes.

Islam et al dwelt on the second most abundant and key photosynthetic enzyme, Carbonic anhydrase (CA), which was known to have a role in carbon fixation, many carboxylation and decarboxylation reactions, photosynthetic electron transport system, maintaining chloroplast pH, respiration, and even protection of enzymes from denaturation. They referred to studies, such as the ones in which TRIA had been noted as the hormone enhancing leaf CA activity remarkably when its 1μM solution was sprayed three times to the foliage of Mentha arvensis L., and at 1.5-ppm level in artemisia leaves over the controls. They also mentioned some others presenting results on marked increases by TRIA sprays onto leaves of several other crops, and finally concluded that the PGR was stimulating CO2 diffusion into the stomata by increasing stomatal conductance, and its assimilation by the increasing activities of CA and RuBisCO enzymes.

As known very well, C and N metabolisms are interrelated, and Nitrate reductase (NR) is essential for N metabolism as the initiator of nitrate assimilation (Foyer, Ferrario-Méry, & Noctor, 2001). On the role of foliar application of TRIA on NR activity, Islam et al concluded that an increase might be responsible for the enhancement of photosynthetic rate and ultimate increase in biomass and productivity. They referred to studies showing that 3 to 5 times foliar spray treatments of 1 μM or 10−6 M TRIA could increase NR activity by increasing within a range of 27.66 to 44.6% in various crops against the controls. In accordance with the interrelated metabolic activities affected by its applications. Islam et al. reviewed the literature on the noticable effects on leaf N, P and K contents in most of the economically important crops, and referred to reports evidenting the significant increments in N, P and K contents of the leaves of various crops compared to their control groups. They added that, as it could be expected, there were studies indicating the improvement of the content and yield of most of the economically important harvests, such as number of fruits, fruit weight, fruit diameter and total yields per plant of Lycopersicum esculentum Mill., yield and yield attributes of wide range of spp, such as Avena sativa L., Malus domistica Borkh., Zingiber officinale Rosc., and others at lower concentrations such as 10−6 M. They attracted attention to a report, which showed that four times application to foliage of Solanum lycopersicum L. could significantly enhance the yield attributes, such as weight, number and yield of fruits per plant by 35.4%, 38.0%, and 57.6% respectively over the controls.

Depending on the importance of the subject for the practitioners, availability of high number of studies gave Islam et al to review and present promising results held on different crops. In their comprehensive article, the literature related with the effects of TRIA on metabolism of active constituents and yield in the essential oil of aromatic and medicinal plants was also reviewed. They referred to studies presenting remarkable effects of the hormone applications on essential oils by increasing their content and yield, such as significant increase in morphine content in Papaver somniferum L. at its 10−6M concentration. Considerable enhancement of curcumin and total alkaloid level in Withania somnifera Dunal L. and Datura innoxia Mill. and other examples lead them to reach a conclusion on the improvement in yield and content of essential oils might be the result of TRIA-mediated enhancement in growth and metabolism.

Considering the relation between oils with other low-energy CHO compounds, carbohydrates, Islam et al. also covered the positive effects of TRIA applications on the content and yield of essential oils and biofuel raw materials. They referred to studies evidenting the effects on the level of essential oils, such as a significant effect on morphine content in Papaver somniferum L., curcumin and total alkaloid content in Withania somnifera Dunal L. and many other crops. Their final conclusion was the reason of improvement in yield and content of essential oils up to 29.7 against controls might be the result of TRIA-mediated enhancement in growth and metabolism of plants.

The importance of the substances in carbohydrate group in biofuel production, lead Islam et al. to feature the topic in their review article, and focussed on microalgae as the most abundant photosynthetic microorganisms. As the most feasible sources for biofuel production with their outstanding capability of CO_2 assimilation shown by experimental studies, they added that microalgal oil was a good source for biodiesel production. They presented evidences showing that several phytohormones were increasing their growth and production of the key metabolites for biodiesel production, referred to studies evidenting TRIA application was also effective in enhancement of growth, chlorophyll, protein contents and biodiesel production in *Chlamydomonas reinhardtii* as some other PGRs. One of the referral study was a comprehensive one, reviewing the literature on the positive effects of auxins; gibberellins; cytokinins; ethylene and its precusors, ABA, TRIA and also some combinations on cell size, growth, biomass, pigments, proteins lipids, and others at numerious unicellular alg spp., including *Chlorella vulgaris, Dunaliella salina, Scenedesmus obliquus* etc. (Xingfeng, Z. H., Bartocci, P. et al., 2018). It was also noted by Islam et al. that 5 mg/L TRIA significantly promoted biodiesel production by increasing biomass and lipid productivity, and ultimately they concluded that the biological roles of phytohormones of microalgae and higher plants were similar; at certain dose ranges they were enhancing the adaptive ability of microalgae against biotic or abiotic stresses by working interactively in the regulation of cellular metabolism enabling them to accumulate biomass and bioproducts. Nevertheless, they said, the scalable and viable microalgal production still required investigations and studies and manipulation of phytohormones on microalgae, to exploit the great potential available for the "Green Revolution" for production of useful biochemicals and alleviation of climate and energy crises.

In accordance with their conclusion, some of the research focus groups in our laboratory studied on the positive effects of TRIA, SA and TRIA + SA on different growth, metabolic parameters of several cyanobacteria and microalgae spp, and also duckweed spp, *Lemna* spp. including their adaptation and resistance to different polluters, at different media and matrix conditions, and also their pollutant remediation capacities [Karacakaya, Kılıç, Duygu, et al. (2009); Kılıç, Karacakaya, Duygu et al. (2010); Aminfarzaneh, & Duygu (2010); Kılıç, Karatay, Duygu, et al. (2011); Taştan, Duygu, & Dönmez (2012), Taştan, Duygu, İlbaş et al. (2012); Taştan, Duygu, Atakol, et al.(2012); Taştan, Ertit, Duygu, et al. (2016).

Al-Maliki & AL-Masoudi (2018) studied on the adverse impacts of soil salinity on soil biological properties and growth of corn plants, which were majorly observed in arid and semi-arid lands. They conducted intelligently designed mesocosm experiments in order to obtain results representing controlled alterations of nutrient availability and food-web structure. They also aimed to eliminate open-system dynamics to be able to investigate the effects of several parameters on the toleration of the corn plants to salinity, and analyzed the effects of mycorrhizal fungi (M) (*Glomus mosseae*), tea wastes (T), algal dried biomass (A), and their combinations on soil respiration, total bacteria, total fungi, soil mean weight diameter (MWD), and corn yield (*Zea mays* L.).parameters under saline and non-saline soils. Results showed them that M, T, and A treatments increased significantly CO_2 release compared to the controls; whereas, M significantly decreased CO_2 release compared to T and A treatments. In non-saline soil, M increased greatly MWD, bacterial and fungal counts, and infection rate. The opposite was true in the saline soil; neither M nor T improved bacterial communities and MWD.; in the saline soil, however M + T was highly efficient in improving MWD, SOC, bacterial and fungal counts, infection rate, and corn grain yield. They concluded that the inoculation of M with T in saline soils could be considered as an important strategy that could increase the toleration of the corn plant to salinity by improving soil microbial activity, MWD, SOC, infection rate, and total grain yield.

Al-Maliki et al. (2018) referred to some studies which evidenced that one of the vital ways to increase the plant toleration to salinity stress was to incorporate the *Arbuscular mycorrhizal* fungi (AM fungi) in soils, which were capable of increasing the endurance of plants to salt stress by enhancing plant nutrient uptake and ion balance and also protecting soil enzymes and soil organic matter, and concurrently facilitating the uptake of water. They added that the combination of AM fungi with T was significantly more effective in increasing the bacterial population than the single addition of the T treatment; due to the the small C:N ratio T might had been rapidly decomposed by microbes and be supporting microbial community for a short period. Their explanation was mixation of AM fungi with the T, the exudates of AM fungi and a presence of protein and amino acids from the T might be stimulating the bacterial growth. They also referred to their previous paper reporting that the addition of T improved the biological properties of soil. In the saline soil, the highest significant increase in bacterial and fungal communities was found in M+T treatment, although it was not significantly different from A+T treatment, the main reason was given as the participation of organic acids and polyphenols in tea wastes in alternating the high pH of the saline soil, and stimulating intensive growth of AM fungi. Subsequent increase in mycorrhizal products could favor the growth of bacterial and fungal populations in saline soils. No effect of A and M treatment on bacterial community was explained by the high C:N ratio of algal dried biomass, which might had degraded rapidly and could not support the bacterial community. Secondly, they said, quantities of algal acids and mycorrhizal exudates were not sufficient to lower the high pH of the saline soil, which was restricting the bacterial population, even though presence of free and bound 1-triacontanol in tea leaves was analytically shown in tea leaves decades ago by a direct gas chromatographic method of identification and determination (Mandayam, Binayak, Dhanaraj, et al. 1988). They added that treatment of the tea leaves with CaO released a bound form in tea leaves. Although this article has been cited only three times until now, Tea Research Institute (UPASI) of Coimbatore city in the Indian state of Tamil Nadu isolated and obtained TRIA from active fraction of tea waste (UPASI, CFTRI-570 020).

In this report issued by UPASI it was noted that TRIA also was extracted from sugarcane press mud & rice bran waste and successful field trials performed to prove its efficacy for high yield in the case of a number of crops like barley, corn, paddy, maize lettuce, cucumber, etc. Tea Research Institute, UPASI, Coimbatore also included the results of successful field trials on tea cultivation, increases in yields to the extent of 20 to 30% and a reduction in dormant shoots (banji). It was added that some of the Agricultural Universities had tried the product on crops like paddy, tomato, brinjal, potato and obtained the results showing remarkable increases in the yields. It was added that number of tea planters in the country tried n-triacontanol and its formulations had shown excellent market potential. The three major raw materials that had been used to extract were tea waste – black tea waste including stiff sweeping, tea waste from instant tea processing, damaged tea, decaffeinated tea wax etc. Sugarcane press mud-obtained as waste product during the clarification of sugar cane juice in sugar factories and rice bran wax extracted from the co-product obtained from the rice milling/ solvent extraction industry. The tea waste was mostly available in tea processing centers, sugarcane pressmud from sugar industries, rice bran wax was available from the solvent extraction units handling rice bran. Comparative yields of n-triacontanol from various waxes were given in terms of Yield % & Purity %: sugarcane pressmud wax 20 & 20, tea waste 30 & 40, and rice bran wax 30 & 25. A feasibility report for the production facility was also presented.

Mori, Tanaka, Nakagawa et al.(2020) investigated chemical uses of Moso bamboo (*Phyllostachys pubescens*) shoot skin, and identified the main component of non-polar solvent extracts as 1-TRIA; GC-MS analyses showed that its concentrations were 13.3 and 41.7 ppm in fresh and boiled skins, respectively. They added that in boiled skins, the concentrations reached to a maximum of 71.3 ppm after 2 weeks of composting, gradually decreased to 19.7 ppm after compost maturation for 6 months. In a further experiment, when seeds of Welsh onion were sown on absorbent cotton impregnated with authentic 1-triacontanol solutions, significant increase in hypocotyl length was observed. They concluded that due to the presence ofthe hormone, Moso bamboo shoot skin had potential as functional compost that could serve as a biostimulant for agricultural uses. Randrianasolo, Krebs, Rakotoarimanga, et al. (2015) isolated 1-triacontanol and 1-icos-17-en-1-ol, 1-octacosanol, umbelliferone and skimmin from the aerial parts, leaves of *Phellolophium madagascariensis* (Apiaceae), an endemic species of Madagascar, which was used as an infusion to treat several health problems ranging from indigestion to skin diseases and nervous disorders.

Ali, & Perveen (2020) studied effect of foliar TRIA application on three cv.s of wheat (*Triticum aestivum* L.) grown on sand and irrigated by full Hoagland solution containing 0, 50 and 100 ppm As ($NaAsO_2$), and they investigated the effects of 1μM TRIA containing nutrient solution on the changes in growth, yield and photosynthetic characteristics. After 16 week of germination, they found that TRIA significantly increased growth and yield attributes, chlorophyll b, internal CO_2 concentration, stomatal conductance, rate of photosynthesis, flavonoids and anthocyanin contents in all wheat varieties. Moreover, the results also indicated that 1 lM TRIA proved to be effective in reducing the adverse effects of As stress on all cv.s. studied. AARI-2011 was more sensitive than Anaj-2017 cv., and TRIA application was more effective on the sensitive one.

Perveen, Shahbaz & Ashraf (2014) investigated the effect of exogenous application of TRIA on two 2 wheat cv.s, S-24 and MH-97 under salt stress in a greenhouse under natural climatic conditions. Both cv.s were grown in full strength nonsaline Hoagland's nutrient solution or 150 mM NaCl containing salty sand cultures. After 0, 10, and 20 μM TRIA foliar sprays at 3 growth stages, i.e. vegetative, boot, and vegetative + boot stages, their data analysis on 92 day-old plants showed that salinity stress adversely affected various growth, physiological, and biochemical attributes in both cv.s at all growth stages. SOD and POX activities decreased in cv. MH-97, catalase (CAT) and POX increased in cv. S-24. H_2O_2, MDA, Na^+, and Cl^- increased in both cv.s at all growth stages. A foliar spray of 10 μM TRIA was found to be more effective in reducing the adverse effects of salt stress on growth, yield, and leaf water relations of wheat plants when applied at the vegetative or vegetative + boot growth stages.

The study of pre-flowering foliar spray of plant growth regulator on growth, yield and quality parameters in Sweet Pepper (*Capsicum annuum* L.) by Sahu, Aslam & Das (2017) was carried out under protected condition to compare the effects of nine treatments viz. 10 and 50 ppm Gibberellic acid 3, (GA3), 10 and 50 ppm Naphthalene acetic acid (NAA), 5 and 10 ppm cycocel (CCC) and 5 and 10 ppm TRIA in Completely Randomized Block Design with three replications. The researchers recorded the observed effects on the basis of five random competitive plants selected from each plot separately for morphological, growth analytical, phenological, and yield parameters, and evaluated them as per standard procedure and also estimated the economics. They found that foliar application of artifical auxin 10 and 50 ppm PGR NAA and 5 and 10 ppm TRIA significantly increased growth and yield attributes, and were presented as better alternatives for boosting, higher production of sweet pepper cv. Pusa Deepti under protected cultivation.

Another important issue regarding the selection of water conservation methods that may be integrated to ecological approaches to agriculture for higher productivity and quality is the mutual growth stimulation among bacteria, algae, fungi, parasitic weeds and non-parasitic plants, as described by Rice, E. L. (1986) in the chapter titled "Allelopathic growth stimulation", in the book titled "The Science of Allelopathy". Examples of plants stimulating growth of other plants including *Ambrosia psilostachya, Agrostemma githago* (agrostemmin), *Medicago sativa* mentioned as a source of triacontanol, rape and pollen of *Alnus* sp. as a source of brassinolides, *Centaurea repens* [*Acroptilon repens*], *C. Solstitialis* and *Glechoma hederacea,* which could inhibit and stimulate growth of different plant spp. It was added that interference of *G. hederacea* with lawn and garden plants was studied using *Bromus tectorum* and radishes as test plants, and found that decaying leaves decreased seed germination, especially in *B. tectorum,* but stimulated root and shoot growth in both test plants. Root exudates stimulated shoot and root growth of radishes but inhibited that of B. tectorum. Cheng & Cheng (2015) reviewed the progress of the research on allelopathy, the common term of biological phenomenon related with the biochemicals produced by an organism influencing the survival, growth, development and reproduction of some other organisms.They covered physiological and ecological mechanisms involved and its use in agriculture in their comprehensive article, by referring to articles evidenting that it was a natural ecological phenomenon. They added that it was known and used in agriculture since ancient times, after the realization of the beneficial effects of allelochemicals on target organisms and easing some agricultural practices, such as weed control, crop protection or crop re-establishment. Allelochemical effects might also be harmful with their autotoxicity, causing soil sickness by creating abiotic and/or biotic stress conditions, such as building soil-borne nematodes, pathogens up or competing for water and nutrients, even invasion of the field. Thus, Cheng et al. (2015) attracted attention to the need of exploiting such cultivation systems in order to take advantage of the stimulatory/inhibitory influence of allelopathic organisms to regulate plant growth and development and to avoid allelopathic autotoxicity.

Focussing on description of management practices related to allelopathy and allelochemicals in agriculture, Cheng et al. (2015) discussed the progress regarding the mode of action of allelochemicals, cytological, histological and physiological mechanisms involved in allelopathic effects. They also evaluated the effects of ecological mechanisms exerted by allelopathy, a sub-discipline of chemical ecology on microorganisms and the ecological environment. They considered also the changes in interrelationships within the ecosystems through the effects of allelochemicals produced by plants or microorganisms on the growth, development and distribution of others in natural communities or agricultural systems. They added that studies on allelopathy started to increase in the 1970s, and the rate of this increase since the mid-1990s had made it a popular topic in botany, ecology, agronomy, soil science, horticulture. Other areas of inquiry in recent years was mentioned as a significant factor contributing to species distribution and abundance within plant communities and in the success of invasions by Cheng et al.. They also drew attention to the possible role of allelopathy in the indirect causes of continuous cropping obstacles in agriculture, and the importance of developing strategies for the management of agricultural production and ecological restoration involving allelopathtic applications including algae, fungi and various microorganisms. They added that after broadening the definition to cover any processes involving secondary metabolites produced by any organisms including viruses by International Allelopathy Society in 1996, the scientific interest in the subject increased considerably

Cheng et al. defined allelochemicals as non-nutritive plant secondary metabolites or decomposition products of microbes consisting of various chemical families which were classified in 14 categories ranging from water-soluble organic acids to complex quinones, purines and nucleosides, PGRs, including SA, GA and ethylene. As the allelochemicals could stimulate or inhibit germination and growth, they could be used to obtain yields with low phytotoxic residues as suitable substitutes for synthetic herbicides, although the efficacy and specificity of many allelochemicals were limited. They attracted attention to number of the studies on the use of allelopathic crops in agriculture showing the beneficial effects that were being realized: using as components of crop rotations, for intercropping, as cover crops or as green manure. Such suitable applications of allelopathy could improve productivity through environmentally friendly control of weeds, insect pests, crop diseases, in addition to of nitrogen conservation, an additional interest, they mentioned, in allelochemicals research was the synthesis of novel agrochemicals based on allelochemicals.

Since competition was one of the main modes of interaction between cultivated crops and their neighbouring plants, arrangement of cropping systems, Cheng et al. said, allelopathy could be used to suppress weeds and alleviate allelopathic autotoxicity to reduce inhibitory influence among allelopathic crops, as several earlier reports had evidented. Exploiting this possibility would mean to improve land utilization rate, increase annual soil output by establishing reasonable crop rotation and intercropping systems. An experimental field study clearly showed them that relative abundance and population suppression of plant parasitic nematodes under *Chromolaena odorata* (L.) (Asteraceae) fallow.

Considering the common intercropping practice in developing countries for maximizing land resources and reducing the risks of single crop failure, Cheng et al. also referred to studies showing the efficiency of intercropping in weed control and biomass production. However, they said, allelopathy between different species might cause promontory or inhibitory effects; therefore, they said, the literature was showing the need to take the allelopathic nature of crops into consideration in crop rotation. Intercropping and stalk mulching to provide economical and sustainable weed management by using allelopathic plants as ground cover species could be an environmental friendly option, as experimentally shown by some studies. They drew attention to allelochemicals from decomposed straw could suppress weed growth and reduce the incidence of pests and diseases, straw mulch could also increase soil fertility by improving organic matter content; but it also might exert negatively by increasing the C/N ratio. The authors cited several impressive references evidenting inhibition of different weeds by the straws in the fields of different crops and reducing the need for herbicide applications, including one presented experimental data on the application of allelopathic plant materials at 1–2 tons ha^{-1} could reduce weed biomass by approximately 70%, and increased rice (*Oryza sativa* L.) yield by approximately 20% in paddy fields over respective controls.

Another potential of allelochemicals that have been exploited was presented by Cheng et al. as the negative allelopathic effects were actually important components of plant defense mechanisms against weeds and herbivory. The technological approaches to modify allelochemicals for the production of environmentally friendly pesticides and PGR's were offering effective management of production by using considerably degradable allelochemicals. They referred to studies showing that formulation of sorgoleone, a hydrophobic compound found in *Sorghum bicolor* (L.) root exudates as a wettable powder. It was more effective in inhibiting weed growth, while crop species were tolerant to it, and some microorganisms were using it as a C source; which could also be mineralized via complete degradation to CO_2 in soil.

The mutually benefical relationship between plants and plant growth-promoting rhizobacteria (PGPR) was mentioned in the review as a mechanism eliciting induced systemic resistance (ISR) reducing susceptibility to pathogenic diseases. References were presented to conclude them that allelopathic bacteria could exhibit PGPR attributes and activity against allelopathic weeds. Cheng et al. added that there were some organic herbicides or plant growth inhibitors that had been manufactured from allelopathic plant materials to inhibit weed growth in fields, and they included a reference presenting the composition of a type of herbicide comprising a mixture of components extracted from several and herbaceous spp., as an example of practical application of plant allelopathy in paddy fields.

Reminding the severity of N leaching water pollution problem related with mineralization of soil organic N, especially nitrification of N fertilizer leading to enrichment of N in the soil, and the gradually increasing importance of biological nitrification inhibition (BNI), Cheng et al. referred to some recent studies evidenting the presence of nitrification-inhibiting substances (NIS) produced by plants, and BNIs were becoming the first choice in soil nitrification management. They also drew attention to the literature showing that BNIs were allelochemicals inhibiting soil nitrification, such as wheat allelochemicals, ferulic acid, p-hydroxybenzoic and hydroxamic acids, which could inhibit soil nitrification microorganisms and reduce N_2O emission. BNIs could also reduce pollution by improving utilization of N fertilizer, the allelopathic inhibition of soil N mineralization by *Plantago lanceolata* L. allelochemical activity on reduction of soil nitrogen leaching was a good example presented.

In the same article, Cheng et al. referred to numerious studies showing the potential of breeding new allelopathic cv.s in order to minimize the introduction of refractory chemicals and weed control. Successful cv.s would be the ones combining weed suppression, high yield potential, disease resistance, early maturity and quality traits. They stressed that presence of a high number of referral studies was proving that this combination was not a surrealistic one, and could be obtained even by conventional breeding. Physiological and biochemical processes and mechanisms underlying allelopathy, related changes in growth, shape, micro- and ultra-structure of plant cells, their walls, organelles and their mitotic activities that were related with the effects of allelochemicals. The imbalances in their antioxidant systems, changes in activities of ROS, redox balances and related enzyme activities, increases in cell membrane permeability as a result of higher membrane lipid peroxidation levels and membrane potential alteration and several other effects had been reported.

The allelopathic effects on the PGR system were also discussed by Cheng et al.; the results of a number of studies on the alterations in PGR contents, imbalances with respect to germination, growth and development, such as the effects of phenolic allelochemicals on IAA oxidase, POD activity on IAA, bound GA or IAA, changes of ABA levels, inhibition of ethylene synthesis by SA, and number of other interactions were presented. Similar changes in the functions and activities of numerous enzymes, such as the inhibition of λ-phosphorylase, the key enzyme involved in seed germination by chlorogenic acid, caffeic acid and catechol, POD, CAT, and cellulase suppression by tannic acid, phenylalanine ammonialyase (PAL) and β-glucosidase by tannic acid were also included in the review article. They also covered the effects of allelochemicals on photosynthesis, respiration, related changes in pigment and ATP metabolisms, water and nutrient uptake, inhibition of Na^+/K^+-ATPase activity which was involved in the absorption and transport of ions at the cell plasma membrane, and suppressing the cellular absorption of K^+, Na^+, or other ions. They referred to several articles on inhibition of ammonium and NO_3^-, Cl^- uptake and K^+ loss by 250 μM ferulic acid by wheat, diminished NO_3^-, SO_4^{2-}, K^+, Ca^{2+}, Mg^{2+}, and Fe^{2+} uptake by cucumber seedlings under the effect of cinnamic acid. They also presented references showing that the effects of allelochemicals on ion uptake were closely related to their concentrations and classifications; at low concentration dibutyl phthalate, for instance, was increasing absorption of N, but decreasing that of P and K.

Cheng et al. also reviewed the effects of some alkaloids possessing allelopathic potential, and focussed on their influences on nucleic acid and protein metabolisms. They added that some could integrate with DNA, or prevent the transcription and translation of DNA by inhibiting DNA polymerase. Some of them could also interfere with protein synthesis, by inhibiting amino acid absorption and transport;

subsequent effect was retardation of cell growth. Phenolic acids could affect the integrity of nucleic acids. They referred to studies showing that the genes involved in reactions of allelochemicals could be categorized as the ones interacting with the environment, subcellular localization, proteins with a binding function or cofactor requirement, cell rescue, defense and virulence, or metabolism. The plant response to allelochemicals was similar to the response to biotic or abiotic stres. Allelochemicals might have relevant functions in the cross-talk between biotic and abiotic stress signaling, as they generate ROS. Cheng et al., in fact, referred to a comprehensive article reporting findings showing that the allelochemical receiving plants were reacting by inducing changes in gene expressions, leading to synthesis of enzymes involved in the biosynthesis of phenolic compounds.

Under the subtitle of "Effects of Allelochemicals on Microorganisms and the Ecological Environment" they discussed the literature that had evidented the presence of significant relationships between crop growth and soil microbiota; importance of indirect effects of allelopathy as a mediator of plant–plant interactions. They drew attention to chemical-specific changes in soil microbes, which could generate negative feedbacks in soil health and plant growth, while the *members* of microbiome rhizosphere were contributing to the allelopathic potential of plants through positive feedback. This contribution was helping to increase inhibition by activating a non-toxic form of an allelochemical, however, Cheng et al. said, bacteria could also help susceptible plants to tolerate biotic stress associated with weeds, and to decrease the allelopathic inhibition of weeds by causing alterations in the expression patterns of some genes. These genes might be responsible for different functions, but they ultimately lead to a self-defense process. Bacterial biofilms in rhizospheric regions could protect colonization sites from phytotoxic allelochemicals by degrading them. In conclusion, they referred to several studies supporting the idea that microorganisms were able to shape the vegetation composition and participate in the control of biodiversity by altering the components of allelochemicals present in the ecosystem. They also presented a **schematic diagram showing the various roles of microbes in modulating the interactions of allelopathic donor-receiver species explaining** how beneficial rhizobacteria could minimize the phytotoxicity of the allelopathic donor by using various rhizospheric processes. This observation was supported by presenting some references on the alteration of plant gene expression by changes in root-colonizing PGPR.

Finally Cheng et al. attracted attention to the complex nature of the allelopathy, covering environmental factors including both abiotic and biotic factors, changes in the composition of the allelochemicals released into the environment, their persistence andd affecting factors. Considering the results of the vast literature on allelopathy showing its application potential in agricultural production at small-scales, regional areas and the disadvantages associated with the methods, such as the evolution of herbicide resistant weeds, pollution, toxicological effects etc., they proposed to create diversity in weed control practices with the application of allelopathy.

Li, Meng, Chai et al (2019) took the greenhouse studies showing improvement of plant drought resistance by arbuscular mycorrhizal fungi (AMF) into consideration, and investigated the effects of AMF on drought resistance and productivity of grassland containing plants with different photosynthetic pathways in field conditions. They reported the results of the *in situ* rainfall exclusion experiment, which was conducted in a temperate meadow and showing that AMF significantly reduced the negative effects of drought on plant growth. On average, they said, AMF was enhancing plant biomass, photosynthetic rate (*A*), stomatal conductance (g_s), intrinsic water use efficiency (iWUE), and SOD activity of the C_3 species *Leymus chinensis* by 58, 63, 38, 15, and 45%, respectively, reduced levels of MDA by 32% under light and moderate drought condition exerted by excluding rainfall 30 and 50% of rainfall respectively. At 70% exclusion level, extreme drought condition, AMF elevated only aboveground biomass and CAT activities. Under light and moderate droughts AMF increased the aboveground biomass, *A*, and CAT activity of C_4 plant *Hemarthria altissima* by 37, 28, and 30%, respectively. As it could be expected the contribution to drought resistance was higher for the C_3 sp. under both light and moderate drought conditions. They concluded that photosynthetic type was important in the magnitude of AMF-associated enhancement in plant drought resistance, thus AMF should be taken as a determinant in plant community structure projections for future climate change scenarios affecting the drought resistance of different plant functional groups.

Li et al(2019) drew attention to the literature reporting that AMF group was one of the most important groups of soil organisms, because they were functioning as mycorrhizal symbionts with the roots of approximately 72% of plants and could improve the growth of hosts by promoting nutrient and water uptake to alleviate the impacts of drought and other abiotic stresses. Since AM fungal hyphae were able to explore soil pores and access to water and nutrient sources that could not be reached by plants themselves, AM were improving plant performance, especially under drought stress. They also referred to some studies, which showed that AMF could also increase WUE by improving stomatal conductance (g_s) and reduce peroxidative damage by increasing antioxidant enzyme activities at greenhouse conditions. There were other experimental studies referred, which had evidented the upregulation of plant physiological performance to tolerate the impacts of drought, salinity, and cold stresses by upregulation of antioxidant enzyme activities and synthesis of jasmonate hormones. Although the knowledge on the biogenic emissions of volatile organic compounds from the higher plants started to accumulate a long time ago, and was reviewed by Fall (1999) in the book titled Reactive Hydrocarbons in the Atmosphere; as far as I see, this topic is still not very popular in evaluation of the effects of abiotic stresses related with global warming.

Fall covered ethylene hormone, but not methyl salicylic acid (MeSA) in his article, Liu, Kaurilind, Jiang et al. (2018), however, described the role of this volatile hormone in their article as a long-distance signal transduction chemical, that was playing an important role in plant responses to abiotic stress and also herbivore and pathogen attacks. They added that, it was unclear how photosynthesis and elicitation of plant volatile organic carbons (VOC) from different metabolic pathways respond to MeSA doses.

Liu et al (2018) applied different MeSA concentrations, within 0-50 mM range, to study alterations in VOC profiles of silver birch (*Betula pendula* Roth) leaves from application through 23 h recovery period. They showed that the application significantly reduced net assimilation rate in 10 mM and 20 mM MeSA-treated plants, without any significant effects on the stomatal conductance, elicited emissions of benzenoids (BZ), monoterpenes (MT) and fatty acid derived compounds (LOX products). While emission rates of benzenoids (BZ) were increasing, emission rates of monoterpenes (MT) were decreasing with the increase of MeSA concentrations; but total emission of LOX products was not influenced by changes in MeSA concentration. They reported that emission rate of MT was negatively correlated with BZ, and its share in the total emission blend decreased, the share of BZ, on the other hand, increased with increasing

MeSA concentration. Overall, they said, the results demonstrated inverse responses of MT and BZ to different MeSA doses; lower doses induced plant defense mechanisms leading mainly to enhanced MT synthesis, whereas greater doses triggered BZ-related defense mechanisms. Liu et al. assessed the results as the evidences that would contribute to improving the understanding of induction of birch defenses upon regular herbivore attacks and pathogen infections in boreal forests.

As shown by Aminfarzaneh et al. (2010) TRIA and SA could support each other in increasing the growth and pollutant resistance of cyanobacteria; Baba, Ali, Kumar et al. (2017) found that, although the growth characters and yield of strawberry (*Fragaria* x *ananassa* Duch. cv. Camarosa) increased by 2 mM SA and 10 μM TRIA foliar sprays; but, their effects were not additive for all the studied parameters. This is another example of the need for organizing the research projects by selecting prospective parameters and combining efforts for finding efficient solutions to mitigate the harmful effects of global warming and climate change.

Agroforestry, for instance does not receive much attention from plant physiologists, although it is accepted as a practice for sustainable land use system, an alternative form of biological reclamation of soils apart from sustainable production, continuous income, regular employment along with food and nutrition security, as described by Behera, Nayak & Patel et al. (2015). The results of their study showed that trees grown with grain crops, horticultural crops or pastures resulted in improvement of physical and chemical properties of soil under various agroforestry systems. Improvement of water permeability and water holding capacity, infiltration rate and hydraulic conductivity, soil fertility enhancement and other features were the characteristics of soil as influenced by tree species, as well as through agroforestry practices.

The article on the contribution of agroforestry trees to nutrient requirements of intercropped plants published 25 years ago, which was mentioning that prunings of several tree species were containing sufficient nutrients to meet crop demand with the notable exception of P by Palm at 1995, and cited in 231 research papers. In spite of the of the academic interest, even the titles of some recently published articles on agroforestry show that it is still not a well understood and widely accepted in practice. "Building Agroforestry Policy Bottom-Up: Knowledge of Czech Farmers on Trees in Farmland" by Krcmarova, Kala, Brendzova (2021), "Changing the Agriculture Paradigm in the Brazilian Atlantic Forest: The Importance of Agroforestry" by Tubenchlak, Badari, Strauch et al. (2021) can be presented as good examples of this neglectance.

As a matter of fact, Miller, Ordoñez, Brown, et al. (2019) complained in the "2.4 Results and authors' conclusions" section of their comprehensive article that, although their study had revealed rigorous evidence on the positive effects of agroforestry, the interventions on farmers' land was remaining extremely limited. They found this result especially notable in the light of the present large volume of literature documenting the uptake of specific agroforestry practices, and also widespread promotion of agroforestry as a strategy to advance the Sustainable Development Goals (SDGs) 2030 by UN. They added that, it was also surprising to observe the general reluctance in spite of the given the relative prevalence of impact evaluations in the related fields of agriculture and forestry. The studies proved that a major benefit of agroforestry was the maintenance of soil fertility, this conclusion is based primarily on observations of higher crop yields near trees or where trees were previously grown. Recent objective analyses and controlled experiments have addressed this topic. This paper examines the issues of tree prunings containing sufficient nutrients to meet crop demands, as referred above.

The article by Carvalho de, Tavares, Cardoso et al. (2010), was one of the publications stressing the importance of beneficial biological interactions between micro-organisms and plant species, especially those formed by AMF and roots. After reminding the viability of AF systems as an alternative to the preservation of natural resources and contribution to food production, they added that the contribution of beneficial biological interactions were increasing the soil volume explored by the roots, nutrient absorption, protection of the roots against pathogens, toxic elements and certain heavy metals, helping the formation and maintenance of soil structure, increasing the input of soil C, and contributing to the maintenance of biodiversity. The potential of the AF systems to maximize the benefits associated with AMF could consecutively mitigate negative interactions between trees and annual crops, and this special symbiosis was deserving further studies. Although they noted the challenges in evaluation of impacts of complex AF systems, they stated that the presence of multiple benefits of AF contributing to a number of the SDGs simultaneously should be taken into consideration, and many more high-quality studies on the effects of AF interventions on agricultural productivity, ecosystem services, and human well being should be performed without losing time.

Rouffael & Colla (2020) also drew attention to the concomitant challenges of rising productivity in agriculture while reducing the environmental impacts. They reviewed the developments in the use of environmental-friendly natural plant biostimulants (PBs) that were shown to improve the tolerance against a wide range of abiotic stressors, in addition to flowering, plant growth, fruit set, crop productivity, and NUE. They added that the European Commission had assigned an ad hoc study on plant biostimulants to evaluate the substances and materials involved; referring to the related publication, they conveyed the definition as “Plant biostimulants are substances and materials, with the exception of nutrients and pesticides, which, when applied to plant, seeds or growing substrates in specific formulations, have the capacity to modify physiological processes of plants in a way that provides potential benefits to growth, development and/or stress responses”. Rouffael & et al. (2020) specified PBs as very heterogeneous materials, such as humic substances, complex organic materials obtained from agro-industrial and urban waste products, sewage sludge extracts, composts, and manure, beneficial chemical elements, such as Al, Co, Na, Se, and Si, inorganic salts including phosphite, seaweed extracts obtained from brown, red, and green macroalgae, chitin and chitosan derivates, kaolin and polyacrylamide antitranspirants, free amino acids and peptides, polyamines, betaines, excluding microbial biostimulants. They referred to an updating report titled as “Biostimulants in Horticulture”, which was supported by scientific evidence about the mode of action, nature and types of effects of PBs on agricultural and horticultural crops: “A plant biostimulant is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrient content”, and stated that it could be completed by adding “By extension plant biostimulants also designate commercial products containing mixtures of such substances and/or microorganisms”to it.

Rouffael et al. (2020) referred to some articles published in 2015 on categorisation of PBs: chitosan, humic and fulvic acids, protein hydrolysates, phosphites, seaweed extracts, silicon, AMF, PGPR; and Trichoderma spp. They added that according to the new EU Regulation 2019/1009by, a plant BS should be an fertilising product stimulating NUE independently of the product's nutrient content by improving one or more characteristics of the plant or its rhizosphere, abiotic stress tolerance, quality traits, or availability of confined nutrients in the soil or rhizosphere. BSs have been classified accordingly on the basis of agricultural function claims of the diverse bioactive natural substances: humic and fulvic acids, animal and vegetal protein hydrolysates, macroalgae seaweeds extracts, silicon, and beneficial microorganisms including AMF and N-fixing strains of Rhizobium, Azotobacter, and Azospirillum. However, Rouffael et al. added, as the justification of agricultural claims had been considered in accepting PBs as sellable in EU market, the members of the European Biostimulant Industry Council had proposed general principles and guidelines for trials and assays to follow when justifying PBs claims.

By drawing attention to the publication of more than 700 scientific papers within 2009–2019 period on the topic, Rouffael et al. clearly demonstrated the capability of microbial and non-microbial PBs in inducing an array of morpho-anatomical, biochemical, physiological, and molecular plant responses, such as boosting crop productivity, NUE and increasing tolerance against abiotic stresses. On the implications for agronomic and physiological traits of crops, they referred to some studies relating the stimulation of germination, seedlings and plant growth, crop productivity to the action of signaling bioactive molecules in the primary and secondary metabolisms. They gave gelatin hydrolysate treatment as an example, which was shown to increase the expression of genes encoding for amino acid permeases, transporters of amino acids and nitrogen. These effects lead them to conclude that the hydrolysate was a biostimulant and sustained source of N. Rouffael et al. also presented a number of experimental research reports evidenting that some commercial PBs boosted shoot fresh weight, or stimulate the growth of epiphytic bacteria such as *Pseudomonas* and *Bacillus* spp. with Plant growth promoter (PGP) synergistically with organic compounds against pathogens, and so on. They added that use of bioactive natural substances and microbial inoculants were representing a valuable tool to enhance soil nutrient availability, increased NUE and nutrient assimilation, in particular N and P, which are known to be fundamental for economical and environmental reasons.

Under the subtitle “Implications of Biostimulants for Abiotic Stresses Tolerance” Rouffael et al. referred to an article stressing the importance of 70% of yield gap imposed by unfavorable environmental and soil conditions, which were dictated by global climatic changes. Another increase expected was the negative impact posing serious concerns on crop productivity and worldwide food security. They also made mention of another study suggesting the application of non-microbial and microbial PBs, in order to overcome this situation as one of the most promising and efficient drivers toward further yield stability. Presentation of several experimental studies supporting this conclusion, such as the metabolomic approach that had allowed the identification of the molecular mechanisms of improved drought tolerance following the BS treatment is definitely convincing. Improved tolerance to ROSmediated modulation of phytohormones and lipids profiles, hormonal effects of an animal-based protein hydrolyzate (PH) containing L-α amino acids, free amino acids, organic-nitrogen, iron, and potassium on water-stressed tomato plants, the application of animal-based PH benefited an antioxidant protection and exerted a major hormonal effect in tomato water-stressed leaves by increasing the endogenous content of auxin, cytokinin, and jasmonic acid can be mentioned as few examples given by Rouffael et al. here.

They referred to a study reporting and evaluating physiological and molecular responses of tomato plants towards two AMF strains, which promoted their tolerance toward drought stress. One of the strains was found to be more effective on VOC production, the other exhibited the best performance traits by increasing WUE under severe drought stress, and was effective against combined abiotic and biotic stresses. In another referral study they presented, it was shown that mycorrhizal plants had higher water extraction rates per unit root length and higher biomass; substrate colonization by AMF that engaged in a functional symbiosis stabilized water retention and enhanced unsaturated hydraulic conductivity of the substrate. Theoretically, they said, enhanced hydraulic conductivity in AMF substrates constituted an effective enlargement of the water depletion zone around roots. Finally, the authors concluded that further studies should investigate how this would quantitatively contribute to water acquisition by plants and the variability of the effect across different soils.

Rouffael et al. also mentioned that several combinations of of several halotolerant PGPR isolates of *Bacillus* spp. isolated from the rhizosphere of durum wheat cultivated in hypersaline environments boosted plant growth traits of mungbean, and this finding lead them to conclude that such specific strains could be used as drought tolerant PGPR under open field conditions. Actually, they presented numerous examples of experimental studies proving that non-microbial and microbial PBs could also be considered a possible way to enhance tolerance to stress conditions, by affecting several biochemical and physiological mechanisms, such as decreased membrane lipid peroxidation, increased chlorophyll content, improved antioxidant activities, and a better efflux and compartmentation of intracellular ions. Another important point they stressed was the demonstration of mitigation of the negative effects of salinity on wheat seedlings grown under saline conditions by the polysaccharides derived from brown and red algae (*Pyropia yezoensis*). Experimental results of a referral study, for instance, lead them to conclude that the lower-molecular weight polysaccharides were effective in protection of wheat seedlings against salt stress damage by coordinating the efflux and compartmentation of NaCl and by enhancing antioxidant activities. The excellent review article by Rouffael et al. conclusively evidented that use of various BS products were offering a vast potiential to be exploited for several purposes; 5-aminolevulinic acid application, for instance, was shown to protect photosynthesis capacity, omeprazole (OMP) was protecting root system, affecting hormonal network by eliciting an increase in ABA, accompanied by a decrease in auxins and cytokinins, as well as a tendency in GA down accumulation.

Finally, Rouffael et al. discussed the value of current achievements and the challenges ahead, referred to the suggestion in a previous article recommending to the main players of PBs, covering scientists, industries, legislators, and stakeholders to focus on the development of a more sustainable and resilient second generation PBs with specific synergistic biostimulatory action through the application of both microbial and non-microbial ones.

Le Bayon, Bullinger, Schomburg et al. (2021) pointed the importance of increase in the recognition of the role of soil science by the engineers out in their review article. They focussed on the role of two parameters, plants and their root systems associated microorganisms and also earthworms. They explained the reason of their selection of these two parameters as 'ecosystem engineers', as they called them, on the grounds of numerous variables, such as texture, porosity, nutrient, and moisture dynamics controlling their activities in space and time, namely hotspots and hot moments. Then, they reviewed the roles of these engineers in three soil formation processes: rock and mineral weathering, soil formation, structure, stabilization and disintegration, finally bioturbation processes; they also covered the mechanisms involved at spatial scales, ranging from local to landscape.

It was added by Le Bayon et al. (2021) that tree uprooting was playing a key role in rock weathering and soil profile bioturbation, the living and dead roots had contribution to rock alteration and aggregation. Earthworms were mainly involved in the formation of aggregates and burrows through their bioturbation activities and also in weathering processes to some extend. They showed the contributions of the two main ecosystem engineers to provision and regulation of services through burrowing and soil aggregation, and also increasing plant productivity, water infiltration, and climate warming mitigation by acting as catalysts and providing, transforming and translocating organic matter and nutrients throughout the soil profile. They added that the concomitant contributions of their inter- and intraspecific interactions and/or symbiosis with microorganisms were increased soil fertility, decreased parasitic actions, and bioremediation of some pollutants. Considering these benefits, Le Bayon et al. noted that better understanding of the relationships between soil management, agricultural practices and soil biota was needed for relevant maintenance and durability of ecological services.

The President of the World Farmers' Organisation (WFO) since June 2017, De Jager, T. (2021) wrote in his article titled "Do You Want to Tackle Climate Change in Times of Pandemic? Roll Up Your Sleeves and Put Your Fingers in the Soil!" that Before COVID-19 outbreak protecting the Planet while ensuring Food Security was the priority number one in the international community. In the pandemic era, he said it was key to leverage to build back better and incorporate a reinvigorated approach to both mitigation and adaptation to ensure food security for a growing global population to enhancing biodiversity. As several referral researchers in the present article, he also mentioned a key ingredient of success was a coordinated, mutually beneficial and trustworthy engagement of the different stakeholders in different sectors of the whole food value chain at multiple levels. He reminded the foundation of "The Climakers"global farmers driven initiative in 2018 in World Farmers' Organisation, which took the Organisation into every corner of the globe. He added that, this initiative let them to discuss how to *trade a little lighter across the pastures and to make a smaller footprint across the cultivated fields.* The Climakers multistakeholder alliance, he said, was giving the farmers the chance to cooperate with all other actors in the value chain, research and civil society to promote better national commitments and ensure long-term sustainability on a healthier planet. He added that thinking on climate change in the perspective of food systems, there was only one entry point to all the challenges for every farmer: **soil health**.

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DAM RESERVOIRS and WATER MANAGEMENT

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Abstract

From the beginning of human history, for almost 5 000 years, dams have served to ensure an adequate supply of water by storing water in times of surplus and releasing it in times of scarcity, thus also preventing or mitigating floods and making a significant contribution to the efficient management of finite water resources that are unevenly distributed and subject to large seasonal fluctuations.

Purposes to be served by such a project usually include water supply, irrigation, flood control, hydropower generation, navigation, recreation, pollution abatement, industrial use, fish and wildlife conservation, and other environmental considerations, salinity, and sediment control, and recharge of groundwater. To meet these purposes, several dams are constructed to control and regulate the natural flows. This regulation function is the main reason for creating reservoirs by constructing dams.

Water storage facilities are being constructed in Turkey as in any other country in the world, to make benefit of water resources which are not regular in terms of time and space, being aware of the fact that total level of the amount may be enough in any given year or long term period. Water storage facilities are also being constructed in order to prevent floods and other water damages. So far in our country, 195 large dams and 941 smaller *dams (that have heights lower than 25 m.*) have been constructed. At present, the number of 110 large dams and the number of 237 smaller dams are being constructed. The number of diversion dams, however, is not considered in this total number.

Giving some figures from the water resources projects in Turkey, this paper generally presents the role of dams in water resource management.

Keywords: Dam, Water storage, Dam reservoir, Dam's benefits, Large dams

1.INTRODUCTION

1.1 Uses of Dams and Reservoirs

Water Dams and Reservoirs have primarily been used to serve four functions (Lindström, Andreas; Granit, Jakob 2012):

- Irrigate crops
- Provide hydroelectric power
- Supply water
- Control flooding

Out of the 38,000 large scale dams registered by the International Commission on Large Dams (ICOLD), an international organization that sets the standards for dams, 50 percent are used for irrigation, 18 percent for hydropower, 12 percent for water supply, and 10 percent for flood control and the rest for other functions (Lindström, Andreas; Granit, Jakob Aug 2012).

1.2 Basic Concepts of Dam Reservoirs

The word "reservoir” is originally stemming from “to reserve”. In this meaning, this word implies to keep something for a special purpose. Accordingly, keeping the water for some special purposes, dams are a major source of hydroelectric power, flood protection, recreation, and domestic, agricultural, and industrial water supplies.

A dam is a structure built across a stream, river, or estuary to retain water. Its purposes are to meet demands for water for human consumption, irrigation, or industry; to reduce peak discharge of floodwater; to increase available water stored for generating hydroelectric power, or to increase the depth of water in a river to improve navigation. An incidental purpose can be to provide a lake for recreation (Kenneth D. Frederick 2003).

While water demand is steadily increasing throughout the world, freshwater resources remain limited and unevenly distributed. Water availability is critical to any further development above the present unsatisfactorily low level, and even to the mere survival of existing communities or to meet the continuously growing demand originating from the rapid increase of their population (Lecornu, Jacques; 1998).

Dams are considered an important issue in the sustainable management of our finite water resources. Those resources are subject to increasingly competitive demands as global population growth exacerbates tensions over the water needed to produce energy and to ensure food security.

Dams store water in the reservoir during times of excess flow, so that water can be released from the reservoir during the times that natural flows are inadequate to meet the needs of water users. Dams are important because they help people have water to drink and provide water for industry, water for irrigation, water for fishing and recreation, water for hydroelectric power production, water for navigation in rivers, and other needs. Dams also serve people by reducing or preventing floods.

1.3 Purposes of Dam Reservoirs

There are various water demands, including irrigation; domestic uses (showering, watering lawns and gardens, etc.); industrial uses (water used for processing, washing, and cooling in facilities that manufacture products); thermoelectric power uses (water used for cooling to condense the steam that drives turbines in the generation of electric power with fossil fuels and nuclear or geothermal energy); and in-stream water uses (water used for hydroelectric power generation, navigation, recreation, and ecosystems) (Kenneth D. Frederick 2003).

The purposes of dams are grouped into two main categories, single-purpose dams and multipurpose dams (Asmal, Kader; (1998).

According to the World Commission on Dams (WCD) Study conducted all over the world, most (48% approx.) dams in the first category are for irrigation and therefore contribute greatly to food production. A considerable proportion (15% approx.) of single-purpose dams serve for domestic and industrial water supply. A substantially smaller number (20% approx.) generate electricity. The same study informs that other purposes include, in decreasing order of importance, flood control (8%), recreation (4%) and, to a lesser degree, inland navigation and fish farming, and that multi-purpose dams account for a large proportion of the total -7 400 out of the 25 400 reported - nearly 30 percent of the total. It is also added that multi-purpose dams are increasingly important for regional economic development.

The majority of large dams are built for irrigation; almost all major dams are built for hydropower. Nearly one-fifth of the world's electricity is generated by dams. Dams also provide flood control, supply water to cities, and can assist river navigation. Many dams are multipurpose, providing two or more of the above benefits.

Irrigation comes first in this category also, followed by flood control, hydropower, domestic and industrial water supply, and recreation, with fish farming and navigation.

Since the groundwater reservoirs presently tapped to provide about half of the irrigation, drinking and industrial water supply are already heavily overdraw in many parts of the world, the only large-scale solution apart from saving water is to increase the share of surface water from the storage reservoir.

According to the WCD Study, flood control has always been a particularly significant motive for dam construction and frequently its primary purpose. In the WCD Report, it is informed that it will continue to be so, as long as about 40 percent of all fatalities from natural catastrophes worldwide are caused by flooding.

Compared with the main requirements of irrigation, domestic and industrial water supply, energy production, and flood control, the other purposes and benefits of dams such as navigation, fisheries and tourism, improvements to the infrastructure, job creation, and on-site training, are of generally minor importance, but must nevertheless not be disregarded or underrated.

1.4 Major Benefits of Dam Reservoirs

According to a study (USCOLD (1999) conducted by the United States Committee on Large Dams (USCOLD), today's living conditions of billions of people are certainly improved by the construction of dams. Besides the essential need for potable water, production of food through irrigation, energy, and power production, flood control, provision of recreational facilities are among the major benefits of dams. Regarding the benefits of the dams, the following aspects could be listed as follows (Yıldız D, Özgüler H 2017):

- In general meaning, dams allow rivers to be used for navigation.
- Dams create lakes for fishing and recreation.
- Dams are important because they provide water for irrigation.
- Large storage dams regulate the flow of water and sediments down the river and impact the functions and services of downstream ecosystems and their biodiversity in many different ways, especially for wildlife or for fisheries for example.

As we are all well aware, one of the major benefits of dams is the production of hydroelectric energy. Generating clean energy of hydropower, dams contribute significantly to reducing air pollution. Hydropower is the most plentiful and most efficient renewable energy resource, contributing a considerable percent of all renewable electric energy produced all over the World. According to the study realized by the USCLD in the USA, the efficiency of a modern hydropower plant exceeds 90 percent, which is more than twice the efficiency of a thermal plant.

Dams provide "cheap" and "clean" energy, increase food production, and control flooding. Examples of this preconceived bias include: The rationale for the development of large dams is based on the generation of clean power and improved management of water resources

According to the World Bank Report (WB Report 1998), namely "The World Bank’s Experience With Large Dams: A Preliminary Review of Impacts”, without the exploitation of rivers, the world would be a much different place and would be able to support fewer viable human settlements. Life for many people in the great river basins of the world would be a cycle of drought, floods, and famines.

However, this report which was prepared by WB Operations Evaluation Department has been heavily criticized by another study (Mc. Cully, Patrick 1996) conducted by International Rivers Network (IRN). Availability of water can also lead to significant greening of barren lands. Yet another benefit often cited is the creation of habitats for water bodies. As an example, it is informed in the different sources that many of India's bird sanctuaries are located on and round artificial reservoirs. On the plus side again, the dam will be capable of pumping out electricity from the generators, each equal to a medium-sized nuclear reactor. This cleaner hydroelectric power would offset the burning of polluting coal, prevent catastrophic flooding (Yıldız D, Özgüler H 2017).

1.5 Concerns on the Dam Reservoirs

Prof. Kader Asmal states that dams provide electricity and fill irrigation canals to boost industrial and agricultural growth, as well as managing floods and storing waters for times of drought. He also stresses that these benefits sometimes come at certain costs in social, economic, and environmental terms, implying the adversarial debate over dams illustrates the tensions between nations (over shared waterways) and within nations (as environmentalists, communities displaced by dam reservoirs, and other affected people battle government, utilities, and farm interests).

Dams can provide hydropower, irrigation, and flood control. These are developmental benefits, but there are also costs in human, environmental and economic terms. The public debate on large dams has been characterized by the increasingly adversarial tone adopted by dam advocates and opponents. The breakdown in constructive dialogue between interested parties in the dams debate has had ramifications in areas ranging from the achievement of civil society consensus on sustainable development to the availability of financing for dams and their alternatives(Yıldız D, Özgüler H 2017).

There are some concerns that water uses is contributing to drought. This is believed to mainly a result of the considerable amount of evaporation losses from the huge sizes of surface areas of reservoirs.

Large dams have provoked opposition for numerous social, environmental, economic, and safety reasons. The main reason for opposition worldwide is the huge numbers of people evicted from their lands and homes to make way for reservoirs.

The livelihoods of many millions of people also suffer because of the downstream effects of dams: the loss of fisheries, contaminated water, decreased amounts of water, and a reduction in the fertility of farmlands and forests due to the loss of natural fertilizers and irrigation in seasonal floods. Dams also spread waterborne diseases such as malaria, leishmaniasis, and schistosomiasis.

According to a study conducted by Ron Corso, Mead & Hunt, Inc., dams can stop regular annual floods but often fail to hold back exceptionally large floods. Because dams lead people to believe that floods are controlled, they lead to increased development of flood plains. When a large flood does come, damages caused are often greater than they would have been without the dam.

When these high costs, delays, and risks of low river flows are factored into calculations of the costs of electricity it can be seen that hydropower is now an expensive form of power generation. Some scientists do not consider hydropower as clean power because of the destruction of river ecosystems and its many social impacts. Internationally, private investors in power projects are largely avoiding large dams and prefer to invest in cheaper and less risky gas-fired power plants.

1.6 Dam and Irrigation

Dams have played a key role in the development since the third millennium BC when the first great civilization evolved on the major rivers. The vast quantities of water in reservoirs allow them to act as effective and steady sources of water for irrigation with minimal seasonal fluctuations. 30 to 40 percent of the 271 million hectares that are irrigated worldwide rely on irrigation dams (WWF 2013). A study (WCD 2000) done by the World Commission on Dams (WCD), a commission organized by the World

Bank and the World Conservation Union (IUCN) to assess the effectiveness of large dams, showed that dams built for irrigation typically are unable to provide water for the planned area of land initially, but the performance improves over time (UNEP 2013).

According to a WCD study (WCD 2000), half of the world's large dams were built exclusively or primarily for irrigation and are estimated to contribute 12-16% of world food production.
About 1,6 billion people depend on food produced by reservoir-related irrigation. There is no alternative of how this food could have been produced by other means

Most of the dam projects not only have the objective of economic benefits, but they also address the overall socio-economic development of the people in the region. The major irrigation projects, which are dependent on dam construction, often help prevent the mitigation of rural people to the cities, while giving them a higher standard of living in their native areas.
Water scarcity affects many countries of the world. Thousands of dams have still to be built to store water and make it available, during the first half of this century, on a worldwide basis, especially in the developing countries.

1.7 The Role of Dams in Hydroelectricity Generation

It is a well-known fact that energy is one of the most important commodities for the satisfaction of physical needs and for providing economic development of modern society. Meanwhile, energy needs are continuously growing. The demand for electric power continues to grow rapidly.

Recently, new problems have evolved with the exponential growth of electrical energy demands. However, these are the issues of water supply for energy production and the impact of energy developments on climate and the global environment(Yıldız D, Özgüler H 2017).

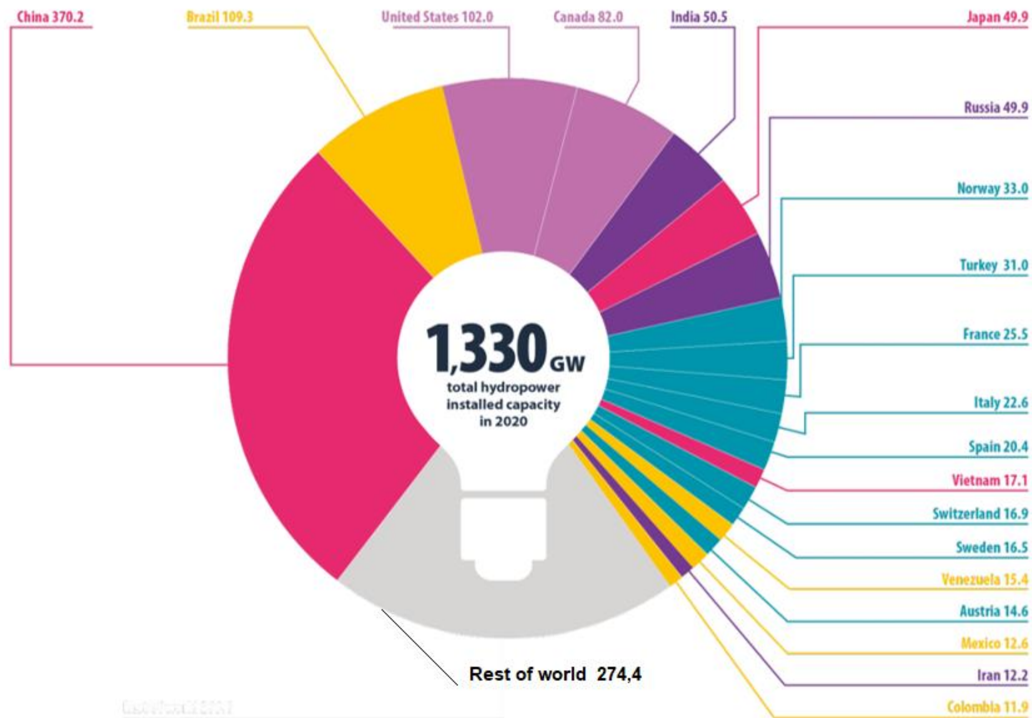

Figure 1. Global hydropower installed capacity in 2019 (iha Report 2020).

Dams do help mitigate climate change by avoiding the emission of greenhouse gases. According to the study (Selek B., Aksu H. (2020), Seyhan Dam is found as a good example of adaptation to climate change impacts by storing water for irrigations and enabling farmers to cope with the variability of the rainfall while adapting to the reduced water resources available in Turkey where water potential changes substantially at temporal and spatial scales as does the climate (Selek B., Demirel Yazici D., Aksu H., Özdemir A.D. 2016). To date, the world energy market has depended almost entirely upon non-renewable, but low-cost, fossil fuels. According to the International Energy Agency, the energy produced by hydroelectric developments throughout the world provides approximately one-sixth of the world's total electrical energy (Figure 4).

Projects totaling 15.6 GW in capacity were put into operation in 2019, Total global hydropower installed capacity reached 1,308 gigawatts (GW) in 2019. (Figure 1). Fifty countries added hydropower capacity in 2019. The countries with the highest individual increases in installed capacity were Brazil (4.92 GW), China (4.17 GW), and Laos (1.89 GW) (iha Report 2020).

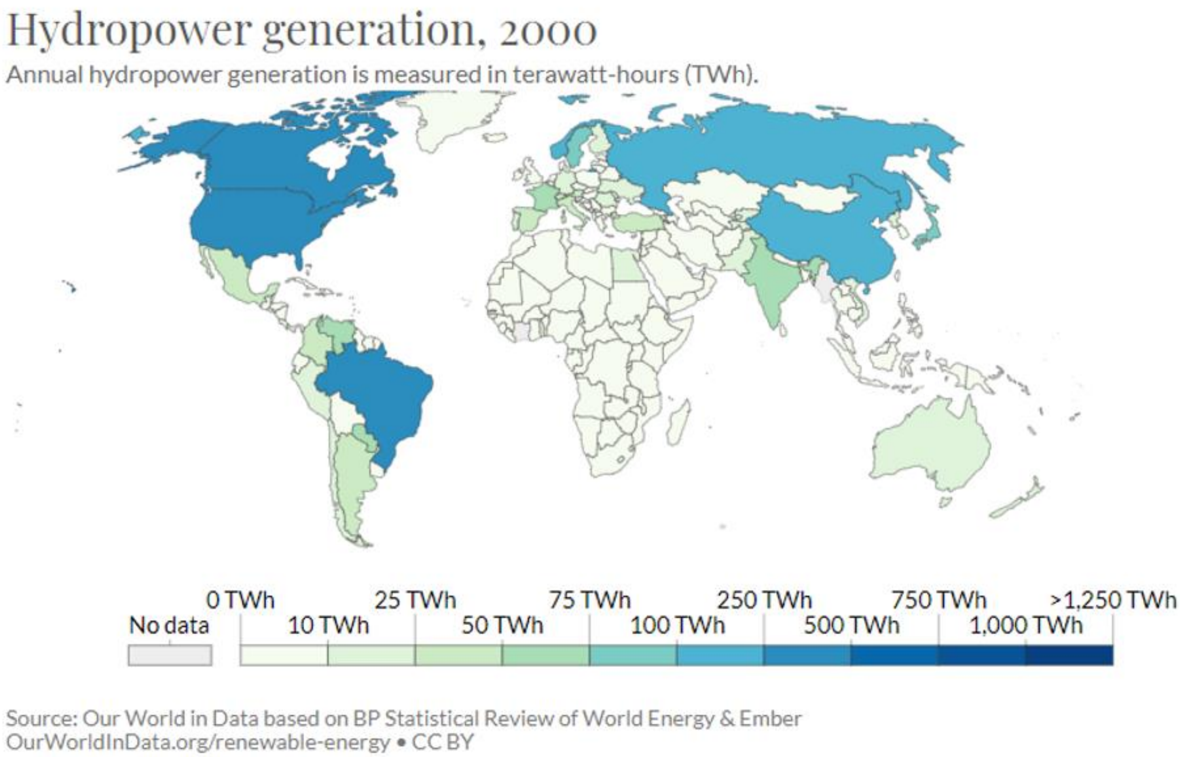

Figure 2.Hydropower generation in 2000

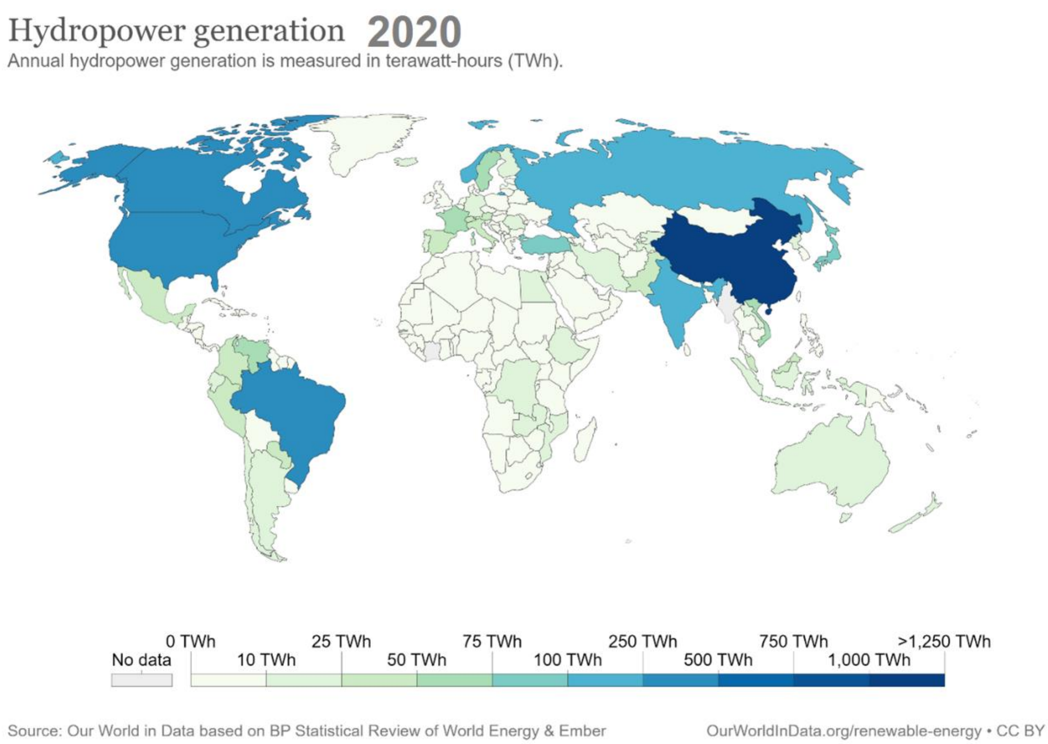

Figure 3. Hydropower generation in 2020

As shown in Figure 2 and Figure 3, China has rapidly developed its hydro energy potential since 2000. Given the foreseeable depletion of fossil fuels, which presently are used to satisfy three-quarters of primary energy requirements worldwide, plus the problem of the greenhouse effect and global warming, there is an urgent need to gradually replace them with methods of energy production which do not release CO_2, (or airborne mercury from coal-fired plants) into the atmosphere and which draw on renewable sources of energy. In the short and medium-term, however, the predominant sources of renewable energy that will permit large-scale exploitation will be biomass and hydropower, before new sources like the direct harnessing of the sun's energy by photovoltaics will be ready to make contributions of the same order of magnitude (The Bureau of Reclamation, USA).

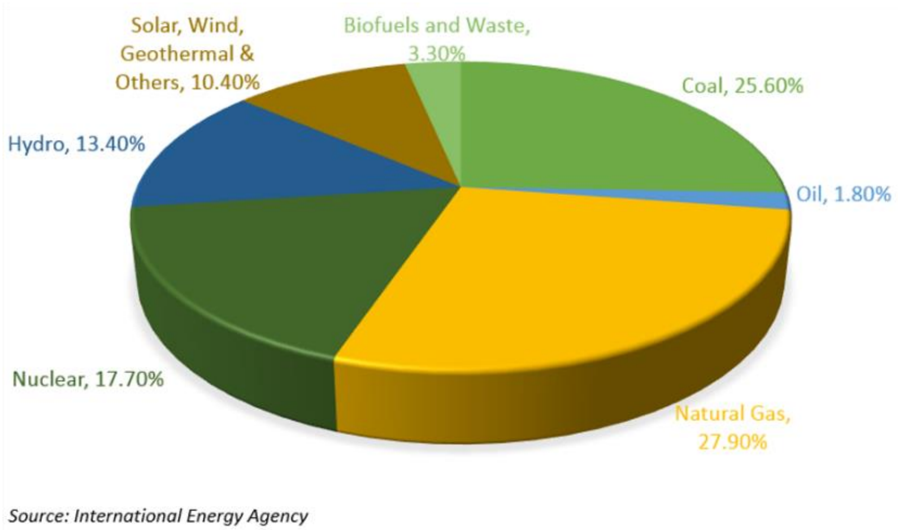

Figure 4 Global electricity generation by source in 2018

Conventional electricity supply options include thermal (coal, oil, and gas), nuclear, and hydropower of different scales. These technologies currently dominate global electricity generation (thermal 55,3%, hydraulic 13,4%, nuclear 17,7 %, solar wind geothermal, and all other 13,7%) (Figure 4). The use of co-generation particularly, and geothermal and wind generation both for isolated supply and small to medium scale grid feeding applications is small but increasing on a global level.

Hydropower has a long list of positive characteristics that explain its strong support and promotion. For one thing, it is highly efficient. In addition to the power generated, the advantages of hydropower are many – such as flood protection (commonly undervalued), flow regulation, multiple-use, and fossil fuel avoidance. The other major beneficial aspects of hydropower can be listed as follows:

- Because hydro is a domestic resource, governments and utilities in developing countries often prefer hydro generation over electricity produced from fossil fuels, which must be imported or, if the nation has its supplies, are valuable sources of export revenues.

- In addition, the relatively low maintenance cost and simplicity of operation associated with hydro projects are strong pluses in countries where the more complex maintenance and operating logistics of thermal plants pose serious problems.
- Although water is one of the two essential components in the production of hydroelectric energy, this is essentially a non-consumptive use as well as a non-polluting one. For example, in the production of thermal-electric energy, water is required in practically all technical stages from the boring of test wells in oil and gas exploration to the transformation of fossil and nuclear fuels into electrical energy at thermal power stations - uses which are largely consumptive and/or polluting.
- Hydropower is a source of electrical energy that is continually renewed and available in the runoff segment of the hydrological cycle. Energy from flowing water offers something unique to a nation's economic development.

Energy experts have a consensus that hydropower is more efficient than most methods of converting mechanical energy to electrical energy, averaging 85 percent efficiency (versus 50 percent for the best gas turbines) and it is more reliable (for example, fewer outages) than any fossil-fueled plant, responding to rapid changes in load and is lower in cost than other types of power.

Hydroelectric plants have a long life, require very little maintenance, and use water, a renewable energy resource. As long as the water continues to flow, nothing else is needed, so no consumption of fuel or production of heat is involved in the electricity generation. After the construction of the plant, very few people are required for the maintenance of the project.

In addition to these good points, because it was possible to transport the energy produced at dams for such great distances, hydroelectric power is commonly considered as a very attractive and economically logical option.

Besides this, very often, hydropower pays for multipurpose benefits. When this is taken into account, and when all environmental and social costs are internalized, hydropower compares favorably with other sources of energy. When compared to other sources of energy, hydropower can be superior, similar, or deficient in comparison. When compared to fossil fuels, a non-renewable resource, hydropower does not produce nearly as much energy. However, hydropower does have the preferable characteristics of being efficient, non-polluting, and renewable (while fossil fuels are quickly becoming scarce and depleted). Hydropower exhibits the same beneficial characteristics over the other non-renewable energy source, nuclear energy. While nuclear energy has the advantage of being able to exist in areas that hydropower cannot (areas of low relief and inadequate amounts of water), "it cannot compare to the cleanliness and inexhaustible amount of fuel used in a hydroelectric plant".

In comparison to other renewable sources of energy, hydropower shares much in common. Both solar power and hydropower need the sun to create energy. Solar power uses the sun's power directly, while the sun evaporates water and deposits it upstream, indirectly making hydropower possible.

Hydropower has the advantage of creating recreational areas for visitors to enjoy. Hydropower, solar power, and wind power all require large amounts of land to generate electricity. Wind power, hydropower, tidal power, and geothermal energy are all limited to locations where the elements needed to fuel the project are available. Hydropower has an advantage over geothermal energy in that it has a continuous supply of fuel. Geothermal plants must consider the "shifting of geothermal activity and the possible exhaustion of the exploited fuel from that area." Biomass too, is renewable, however, it has the disadvantage of producing pollution when burned.

In summary, it is now becoming increasingly clear that the role of renewable hydropower will undergo a qualitative shift over the coming decades. While it will continue to provide low-cost, baseload electricity in many markets, hydropower will increasingly be valued for its flexibility and provide essential support to the huge growth in wind and solar that is needed to limit global warming(iha Report 2020).

There is now more than 1,300 GW of installed hydropower capacity globally. According to the International Renewable Energy Agency (IRENA)'s Global Renewables Outlook 2020, this figure will need to grow by around 60 percent by 2050 to help limit the rise in global temperature to well below 2 degrees Celsius above pre-industrial levels. Such growth would help generate some 600,000 skilled jobs over the coming decade according to IRENA and would require an estimated investment of US$1.7 trillion. (iha Report 2020).

2.WATER POTENTIAL OF TURKEY

2.1 General Information

According to the statistics (15) conducted by the General Directorate of State Hydraulic Works (DSI) of Turkey, all water resources in Turkey are thoroughly observed and evaluated through the hydrological and meteorological network extended all over the country. With mean annual precipitation of 643 mm, it is assumed that yearly precipitation brings 501 km^3 of water. While 274 km^3 of this quantity returns to the atmosphere through evapotranspiration from ground and water surfaces as well as from plants, 69 km^3 feed the underground water reserves through infiltration from the surface, therefore a total of 186 km^3 of which 158 km^3 come from the precipitation and 28 km^3 come from the underground water reserves, flow into the sea and the lakes through rivers and streams of various sizes (Yıldız D, Özgüler H 2017).

Furthermore, based on flow observations it is determined that 7 km^3 water flows into Turkey every year through the rivers from neighboring countries. Accordingly, Turkey's surface flow potential is calculated as 193 km^3 keeping in mind that significant changes may occur every year depending on meteorological conditions. On the other hand, consumable water potential based on current technology and economics is 110 km^3.

There are 26 hydrologic basins in Turkey. The largest five basins concerning yearly water potential are Euphrates (31.61 km^3). Keeping water under control or making arrangements for beneficial use of water constitute the object and aim of the projects intended for developing water resources. Development of water resources including the production of electricity has always been considered to be a national policy and the General Directorate of DSI was established in the year 1954 for the execution of projects under the leadership of a governmental institution.

Owing to considerable variations observed in the run-offs in terms of seasons and years, it is necessary on the major rivers in Turkey to have water storage to ensure the use of the water, when it is necessary. Consequently, for these reasons, priority has always been given to the construction of water storage facilities. Significant progress was registered in the construction of dams throughout more than 50 years elapsed since the establishment of DSI. However, projects which further to their national nature also have an international character owing to water flowing into the lands beyond the national borders often show multipurpose and complex characteristics, as being in the Euphrates River.

2.2.Hydropower in Turkey

To meet the increasing demand, Turkey showing rapid social and economic progress must produce, continuous high-quality, reliable and economical electricity by taking into consideration all environmental effects. Development of projects by making use of the energy resources available in Turkey and making necessary investments for this purpose is therefore required. The local energy sources are hydro, mainly in the eastern part of the country, and lignite. Turkey has a large potential for renewable energy sources(Yıldız D, Özgüler H 2017):

As stressed in the previous sections, for the production of electrical energy, hydroelectric power plants, in comparison with fossil and nuclear fuel thermal, geothermal, and natural gas power plants have two significant advantages as they can be used to generate electricity for peak hours as well as they are renewable. In terms of initial investment cost except for natural gas power plants and some special cases hydroelectric power plants are in a position to compete with other thermal and nuclear power plants. They are the most economically operated power plants causing little damage to the environment.

Turkey is the second-largest producer of hydropower in Europe, behind Norway, with an installed capacity of 29.000 MW. Turkey has generated one forth of electricity from hydropower in 2019. (Yıldız Dursun 2021).

3.CONCLUSION

Today, most of the world's large rivers are dammed. The original purposes of dams were to improve human quality of life by providing drinking water and to support economic growth by diverting water for power, navigation, flood control, and irrigation. In addition to the water they provide, dams also provide energy in the form of electrical hydropower which is regarded as a clean, renewable, and reliable energy source.

Dams and the reservoirs they create protects growing populations from the unpredictability and violence of rivers' seasons. In warm regions, stored floodwaters can supply enough irrigation for a year-round growing season. But the adverse effects of river impoundment-disruption of ecosystems, the decline of fish stocks, forced settlements, and water-born diseases could be listed as the possible negative effects. Therefore dam reservoirs can be considered as an effective tool for sustainable water management

To conclude, with respect to global considerations, the need for development in the Global South of the World is obvious. The economy is almost entirely oriented to agriculture in this part of the world. Climate change negative effect on agricultural production and product variety increase. In order to achieve food security in the developing world, agricultural production has to be increased. This can only be achieved with the development of the region's land and water resources. Reservoirs will play the most important role to reach water, energy, and food security in this part of the world.

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