Some Methods of Water Conservation in Agriculture which may also be Integrated to Achieve Higher Productivity and Quality Ecologically

I. Impacts of Global Warming and Climate Change on Agricultural Production

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Abstract

While global warming is changing the climate dramatically and adversely impacting many aspects of the physiology of plants, and fertility of soils, the need for more efficient use of water in agricultural practices is increasing. Although there are many well established and widely used practices improving water retention and use efficiency in agricultural production, some others still need to be introduced and/or reminded to new prospective users in different regions or to the farmers growing different crops etc. Because, some of the results obtained by researchers in the laboratories or experimental fields do not attract attention of practitioners, or some successful applications in some regions may not draw interest of the scientists and prospective beneficiaries living elsewhere.

It is attempted to review and discuss some of such promising methods and practices here, in order to attract attention to the need of evaluation and assessment of new approaches to find solutions to the intensifying environmental and socioeconomic problems.

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

1.INTRODUCTION

As known, in spite of experiencing the intensifying various impacts of anthropogenic global warming and climate changes, "An important opportunity was lost as COP25 ended in compromise, with a modest agreement, widespread disappointment that no overall consensus was reached on increased climate ambition, The European Union, for example, Committed to carbon neutrality by 2050" was the conclusion reached by United Nations (UN News, 2019). Euronews also regretted by saying "Watch again: COP25 talks end with no deal on carbon trading." (Euronews, 2019). UN News, on the other hand, attracted attention to the declaration of commitments by high number of nations, regions, cities, businesses and investors to reach carbon neutrality by 2050. Famous Swedish activist Greta Thunberg, on the other hand, branded EU legislation to tackle climate change as a surrender, and added that the Green Deal package of measures gave the world much less than a 50 per cent chance to limit global warming to 1.5℃ (Ecowatch, 2020).

It is very difficult to predict the answer of the vital question to be asked at this point, what will happen until reaching carbon neutrality by 2050? Unfortunately there are high number of pessimistic projections, which cannot be neglected (Higgins, 2019; Buis, 2020; United Nations, 2020). Aminzade (2018) in fact, presented data and her evaluations on worsening water problems under the title of "Projections of Future Drought"; Abobatta (2019) drew attention to the chronic water shortage and related soil solution saltiness in Middle East North Africa region.

Loboguerrero, A. M., Campbell, B. M., Cooper, P. J., Hansen, et al. (2019) drew attention to human activities related with land, through agriculture and forestry, impacting functioning of ecosystems, and stressed the importance of agriculture in adaptation and mitigation activities addressing global warming and climate changes to ensure water and food security for the growing global population. They added that climate change and its agricultural outcomes were risking the efforts to reach at least 7 of the 17 Sustainable Development Goals, although 103 nations had committed themselves to reduce greenhouse gas emissions from agriculture, because of the lack of sufficient support in adaptation and mitigation actions within agriculture still receiving insufficient support from local to international level. They reviewed a series of climate change adaptation and mitigation options that could support increased production, production efficiency and greater food security for 9 billion people by 2050, and supported climate-smart agriculture, which could help foster synergies between productivity, adaptation, and mitigation, although trade-offs might be equally apparent. Vandeweerd, V., Glemarec, Y. Billett, S. et al. (2012), on the other hand, attracted attention to the impacts of the heightened financial barriers by rich countries for the vulnerable groups, such as the poor people and women; and concluded that this reluctance was threatening the achievement of poverty eradication goal of global sustainable goals.

There are some sources, such as International Institute for Sustainable Development (IISD), on the other hand, let their readers to reach their conclusions by offering both of optimistic and pessimistic perspectives (Ospina ve Asadollahi, 2017). Actually, the same difficulty is valid for predicting the technological developments in the near future, which can provide applicable solutions to mitigate global warming and avoid most catastrophic impacts of climate change until reaching carbon neutrality by 2050. Such attempts range from scrubbing carbon dioxide from the stacks (Boyd, Chidambaram, et al. 2019) to store solar energy for very long periods up (Wang, Roffy et.al , 2019), to produce and use the nuclear fusion energy (International Atomic Energy Agency –IAEA (2018).

Sustainable food production target covers some solutions which are considered as climate independent ones, such as hydroponics and aquaponics; as Yep and Zheng (2019) put it in their comprehensive review article, aquaponics was offering solutions to limited fresh water availability, pollution, increasing fertilizer costs, depletion of fertile soils. They detailed the current trends and technological advancements, successes and challenges for commercial and research applications. The question to be asked here is the economical feasibility of such techniques for underdeveloped and developing countries. Sulma, Gimenes, and Erlaine (2019) studied on this subject, by describing their aim as examining the economic viability of a hydroponic system using a distinguished approach to treat investment risk, considering the high value of initial investment. Some other factors such as operation and maintenance costs, which may be proportionally higher in underdeveloped and developing countries.

It will be attempted here to review benefits of some of the agricultural practices that have been proved to be environmentally and economically sustainable at some areas, and/or for some production systems, in order to attract attention to their potential in other several application areas. Special emphasis will be paid on climate crisis and water economy in relation with water use efficiency (WUE), classically defined as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop considering the intensity of consequent various stress conditions projected by IPCC and FAO experts [Elbehri, A., Challinor, A., Verchot, L., Angelsen, A., et al. (2017)].

2.CLIMATE IN ECOLOGY

Stenseth N. C., Mysterud, A., Ottersen, G. et al. (2002) reminded the fact that ecological processes were influenced by prevailing climatic conditions and criticised the earlier studies which overlooked: the holistic nature of the climate system, and focused typically on local weather parameters such as temperature, precipitation, and snow depth. They emphasised the importance of increasing attention paid to large-scale patterns of climate variability with marked ecological impacts on interannual and longer time scales, such as North Atlantic Oscillation (NAO), El Nin˜o–Southern Oscillation (ENSO), which accounted for major variations in weather and climate globally and had been shown to affect terrestrial vegetation, distribution of herbivores and carnivores, marine biology and fish stocks directly and indirectly. They stressed the importance of increasing awareness and interactions between biologists and climate scientists in the critical issue of the response of ecosystems to climate variability and climate change; mutual interest in climate processes.

As they put it, climate is a determinant, spatial synchronizer of distribution of populations as described in population ecology as 'Moran's theorem' or the 'Moran effect'. In short, Moran stated that the time correlation of two separate populations of the same species was equal to the correlation between the various environmental variabilities of the habitat, they lived in (Blasius and Stone, L. 2000). Stenseth et al. (2002) gave the example of rainfall changes associated with ENSO, producing a highly synchronic pattern of changes in massive germination of annual plants, terrestrial vegetation and consequently fauna through both direct and indirect pathways over arid and semiarid regions, as described by Lima, Julliard, Stensth and Jaksic (2001) for a small rodent species.

This complex relations network dominates the biogeographical distribution network, which is the subject of biogeography. As Nehra (2016) described, biogeography studies the past and present distribution of the world's many species, often relates to the examination of the physical environment, which affects species, communities, populations and ecosystems, shaping their distribution across space over geological timescales. Organisms and their communities often varied in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area in a very dynamic manner. Biogeographic regions were exhibiting differences in the average composition of flora and fauna, which were the result of historic and current causes were affected by global warming induced climate changes.

2.1 Climate Crisis and Plant Biology

The book by Archer and Rahmstorf (2010) titled "The Climate Crisis: An Introductory Guide to Climate Change", reflected the expression used by Al Gore in his Nobel Lecture, who warned for the threat of the climate crisis, as a threat that was real, rising, imminent and universal (United Nations, 2007). In another document titled "The Climate Crisis – A Race We Can win", it was referred to the speech by who said "The climate emergency is a race we are losing, but it is a race we can win"(United Nations, 2007). Considering the above summarized dominancy of climate in biogeographical distribution of living organisms by limiting the abundancy of autotrophs, it can be stated that biological properties and ecological tolerances of plants are vital factors effective in winning the race against global warming driven climate crisis.

Koricheva and Gurevitch (2014) discussed the uses and misuses of meta-analysis in plant ecology, considering the wider fluctuations in temperatures and increasing levels of aridity in many regions that were making their lives of those highly complex and sensitive organisms more difficult. They added that, even in relatively more stable climate zones today, variations in light intensity could reduce growth rates and crop yields, by exceeding the limits of protective cell physiological mechanisms of the plants, which have been developed to protect them against the deleterious effects of higher light intensities on photosynthesis,. They referred to another study on the genetical control of the level of the enzymes named as V, P, and Z, which were playing the key role in the regulation of the adaptation process. Since overexpression of these enzymes retarded growth, higher levels of photoprotection might be interfering with the operation of other mechanisms involved in plant growth.

The practical aspects of their conclusion can be summarized as follows: Contrary to confident suggestions of some research groups, they found it difficult to produce plants that were better adapted to climatic changes. They evaluated their results as the data evidenting the complication of adaptation of plants to facilitate satisfactory adjustment to changing climatic conditions. There were no simple or universal solutions to enable plant spp. to cope with the challenges posed by climate change. The reason of the complexity was the tight interconnection of the physiological processes involved. It would be impossible to predict the consequences of the effects of multiple changes, thus the relevant approach to adaptation phenomena should be a holistic one. The research team coordinated by Leister involved in analysis of complex relationships and understand how plants reacted to biotic and abiotic environmental factors, such as drought, light and temperature, by analyzing their impact on the concentrations of all measurable metabolites, transcripts and proteins in plant cells, which could lead to identification of the key components facilitating plants to cope with varying conditions, and underlying the trade-offs, mechanisms between growth rates, increases in biomass and yields of crop plants; as they named it, 'assisted evolution' aiming to find sustainable solutions. They referred to some progress that had already been made in certain species of algae, which serve as sources of potentially useful models of genetic mutations that could be introduced into green plants.

Wang, D., Wang, H., Wang, P., et al. (2019) pointed out the lack of information on the effects of different methods used in the studies on the responsive pattern of plant ecophysiology to climate warming. In order to fill the gap, they applied a comprehensive meta-analytical method to climate warming manipulative studies, aiming to reveal ecophysiological aspects of responses to multiple dimensions of climate change and their implications for different species under different experimental settings. They presented results indicating increased specific leaf area and enhanced leaf dark respiration, which were accompanied by decreased net photosynthetic rate and leaf nitrogen content. The positive and negative effects of warming were different for C_4 and C_3 plants, as would be expected, the effects on plant ecophysiological traits also varied among different response variables and by the magnitude of temperature change and experimental methodology.

The literature presented above clearly show the need for utilization of methodology of the studies named as Environmental Plant Physiology, Environmental Plant Ecophysiology, Plant Ecophysiology, Physicochemical and Environmental Plant Physiology, and Comparative Ecophysiology. An attempt was made by Lüttge and Scarano (2004) to delineate the meaning of Ecophysiology and presented a brief historical overview of methodological and instrumental developments along with sampling strategies for analyses of physiological performance in the field. Actually, ecophysiology was developed from aut-ecology, as they pointed out, which was dedicated to the behaviour of individual plants, species or higher taxa, viz. physiotypes, i.e. physical characteristics of organisms distinguishing them in particular habitats, leading to the development of ecophysiological diversity, and ultimately integrative physiological synecological studies on communities. As mentioned by the authors, these communal studies compare morpho- and physio-types within a habitat or ecosystem and across a range of habitats or ecosystems.

The applications of some analytical methods used for such purposes were included in the review article on the environmental physiology of *Musa spp.* by Turner; Fortescue and Thomas (2007). In their brilliant short communication "Focus on Ecophysiology", Ainsworth, Bernacchi and Dohlman (2016) drew attention to the wide range of current environmental challenges and the projections on further warming on natural and managed plant systems, which had adapted to an incredible range of environments. Ecological and environmental plant physiology, which provided mechanistic understanding of their survival, distribution, productivity, and abundance of plant species across the diverse habitats. They added that this could be realized by using the methods of plant physiology to understand the changes in metabolism, water economy and use, hormonal control, responses to abiotic and biotic stresses, from instantaneous to evolutionary timescales and from tissues to canopy, ecosystem, region, and globe scales.

Their conclusion was that, the advancements in ecophysiological understanding and stimulation of adaptation of plant spp. to multiple stresses by breeding climate resilient varieties of field crops, which put plant ecophysiology at the center of understanding plant evolution and productivity, nutrient use efficiency; adaptation potential of spp. and managed ecosystems, acceleration of breeding for higher tolerances, which would also serve to mitigation of global warming and impacts of climate changes.

2.2 Some Critical Parameters of Effects Exerted on Plants by Climate Change

Becklin, Anderson, Gerhart, et al.(2016) summarized the multiple effects of warming climate and their profound impacts on the physiological functioning of plants and interactions between plants and other organisms, and also ecosystems; thus, they combined findings in plant physiological ecology and evolutionary biology. Changes in photosynthetic rates would shift plant growth rates, overall productivity, and resource use, levels of leaf sugars, phenological processes such as dormancy break and flowering time, shifts in source/sink relationships of photosynthate which could influence seedling survival, whole-plant growth and competitive power, resilience against selective pressures put by altered thermal and precipitation regimes and CO_2 level, global warming changes patterns of natural selection on plant physiology, morphology, and life history.

Considering seed and bud dormancy, germination, flowering and defoliation dependence on different factors in genera, classified as neutral, short day, long day plants, viability of species and communities will considerably change in near future. Differences in phenotypic plasticity, root system, water use efficiency (WUE) and soil types will also be elective. As they also stated, species would ultimately have to evolve or migrate change to avoid extinction, and many already had shifted to higher latitudes and elevations or disappeared.

Ramegowda, V. and Senthil-Kumar, M. (2015) reviewed the literature on the effects of combined biotic and abiotic stresses and the consequent limitation on crop yields, considering the scientific developments in understanding the molecular basis of their interactions. They attracted attention to the tailored physiological and molecular responses exhibited by plants as part of their stress tolerance strategy, which could not be inferred from individual stress studies. They focused on the complex physiological changes induced by different signaling mechanisms in cases of simultaneous drought and pathogen stresses, and attempted to highlight the tailored negative, i.e., susceptible or positive, tolerant strategies developed by plants;referred to previous reports evidenting an increase in disease susceptibility of several crops at combined pathogen and high temperature stresses. They concluded that those studies showed that both basal and the *R*-gene-mediated defense responses were suppressed during combined high temperature and pathogen infection, although this trend was not evident in plants exposed to individual stresses. They also added that plant growth inhibitor, Abscisic acid (ABA), the primary regulator of drought stress response was also known as an pathogen response altering agent. Some of the physiological mechanisms involved in the water use, metabolism and economy will be briefly discussed below.

Beckling, et al. (2016) put emphasis on phenotypic plasticity as a fundamental response mechanism to a changing environment, and added that the direction and adaptive value of plasticity could be assessed experimentally by exposing genotypes to contrasting conditions. As typically named, acclimatization or acclimation, stimulation of adaptive physiological response is a method used to decrease the susceptibility of organisms to stress factors, in other words, increasing their resistances, as far as to the limits of their genetic potential. Leuendorf, Frank & Schmülling (2020) described the process as developing strategies to remember the first priming stress to respond to the following one. They observed that Arabidopsis thaliana seedlings exposed to sustained cold treatment developed a higher freezing tolerance, an effective memory which was associated with an altered physiological state and lifecycle, from germination to growth and florescence; although chilling was known to affect growth and development, freezing temperatures led to a state named 'physiological drought', which means wounding and death. They referred to some articles describing acclimation by formation and accumulation of cryo-protectants like e.g. soluble sugars, prolines, flavonoids or anthocyanin, changes in lipid and protein compositions of cellular membranes and major changes in the plant transcriptome and proteome. The synthesis, levels and activities of hormones and inhibitors must be added to the control mechanisms of acclimation and consequent resistance.

Meyers, Ancel, and Lachmann (2005) used a transparent mathematical model to illustrate the concept of genetic potential to show that the relation between decreasing environmental variability and evolvement of populations distinct steady state conditions in terms of organismal flexibility, genetic potential, and genetic robustness. They examined fluctuating selection for hydrophobicity in a single amino acid as a specific example of this concept, and they concluded that environmental fluctuations could produce distinct allele distributions. They also attracted attention to the current rate of environmental changes, which are high and still increasing (Lindsey and Dahlmann, 2020).

Another important series of impacts of climate change are on soils and plant-soil relations, as comprehensively reviewed by Prentice, Cramer, and Harrisont, (1992) and recently by Karmakar, Dutta and Rakshit (2016). Prentice et al (1992) presented a model to predict global patterns in vegetation physiognomy by using physiological considerations influencing the distributions of different functional types of plant, considering the fact that the terrestrial biomes arise as combinations of dominant types. They used global environmental data such as monthly means of temperature, sunshine, precipitation, drought index incorporating the seasonality of precipitation, soil texture class and available water capacity of the soil, and they found good agreement between their predictions of global vegetation patterns and the mapped distribution of actual ecosystem complexes. They listed the driving variables were mean coldest-month temperature, annual accumulated temperature over 5°C, and a drought index incorporating the seasonality of precipitation and the available water retention capacity of the soil. The model was found suitable for predicting the plant types that could fit in a habitat, and selection of potentially dominant types, except where intensive agriculture obliterated the natural patterns. They concluded that the model could be used in assessment of impacts of future climate changes on potential natural vegetation patterns, land-surface characteristics and terrestrial carbon storage. Karmakar et al (2006) also stressed the importance of recent changes of climate and vegetation on soil formation and developments in the soils, in addition to their use and management, considering the importance of climate in the formation of soil with important implications for their development, use and management perspective with reference to soil structure, stability, topsoil water holding capacity, nutrient availability and erosion. They added indirect effects of climate on plant growth rates and water use efficiencies, vegetative cover, organic matter turnover and CO_2 dynamics.

They commented also on the effect of climate change on agricultural production and said that the generally obtained yield much less than the half of the genetically offered potential by a selected cv. at the cultivated site. The deficite should be the result of climate and selected cv. if all other factors were kept optimal at the site, so this consideration lead several agriculturalists, scientists and economists to study on the adverse effects of climate change. They added that the major role of the soil in the determination of yield, inevitably lead the research teams to study on the changes in the physical, chemical and biological properties of cultivated fields. They concluded that, in spite of the progresses in understanding the relationships between particular soil properties and climate change, comprehensive explanation of the key factors involved were still lacking, and their review article aimed to describe the impact of climate change on soil properties, possible mitigation or adaptation strategies. They presented the average yield reducing factors as weeds, pests, diseases and plant density; best farmer yield limiting factors as water and nutrients, attainable yield defining factors as climatic factors and crop characteristics. In the present study, it will be attempted to evaluate the efficiency of some methods, techniques in filling such yield limiting, reducing factors in global warming related climatic changes era, inevitably without going into many details of the topics to be covered here.

Nortcliff, Hulpke, H., Bannick C. G. Et al (2006) for instance, presented an article on the complicated science of soil and its important role in agricultural production in the chapter titled Soil, Definition, Function, and Utilization of Soil. As physics, physical chemistry, chemistry, macro and microbiology and their interrelations involved in soil science, their summary included a list of subtitles starting with Definition, Ecological and Political Aspects of Soil Protection, Function and Utilization of Soil, Soil Ecosystems, Ecological Soil Functions, Regulating Functions, Habitat Function for Organisms in and upon the Soil, Productive Function, Agriculture, Forestry, Other Soil Functions, Utilization of Wastes, Raw Material Deposits, Land Utilization and Soil Destruction (Statistics), Land Utilization, Soil Destruction, and Forecast. Some important terms such as soil structure and texture, soil moisture, soil moisture retention, soil solution, ionic exchange capacity, soil pH were had to mentioned in the subtitles listed above.

Ouyang, H., Lana, S., Yang, H. et al. (2017) studied on another aspect of water retention capacity of soils, non-rainfall water (NRW), the most frequent water source of drylands, could be significantly boosted by biocrusts. They added that the mechanism of biocrustal promotion and utilization of NRW had been little studied, thus they studied on its accumulation patterns, photosynthetic activities and CO2 exchange of different biocrusts (2 cyanobacteria crusts-ACs, 1 cyanolichen crust-LC1, 1 green algae lichen crust-LC2, and 1 moss crust-MC) under NRW through in situ mesocosm experiments in the Hobq Desert of China during the autumns of 2014 and 2015. Structural equation models showed that crustal properties feedback affected the degree of meteorological parameters on NRW accumulation, in which the effect of surface temperature gradually decreased with the development of biocrusts while that of subsoil temperature and light intensity increased. Anyway water is the first limiting factor of lives, especially in drylands. The formation and development of biocrusts also needed water,though the amount is much less than that required by vascular plants, they could utilize additional water sources, such as nonrainfall water (NRW), which could be used by other organisms, but its availability was measured at an older study they referred as approximately 200 nights per year even in the northern Negev desert. Several other studies were mentioned, showing that NRW was comprising a great proportion of the total annual precipitation, or even it was the only water source in some places. They drew attention to the fact that there was a threshold of water availability that could activate carbon fixation, the effectiveness of NRW on biocrusts was of vital importance to determine the boundary of inoculation-based technology, in which the carbon gain particularly related to NRW quantity and duration. NRW was also the most frequent water for the photosynthetic carbon fixation of cryptogams in biocrusts.

They also presented vast literature showing that easily peeled-off biocrusts, firstly colonized and stabilized by cyanobacteria, occupied more than 70% of the living coverage in arid and semi-arid areas, contributing to the stabilization, fertilization, and hydrological regulation of topsoil, fixing sandy surface, which made utilization of biocrust technology. Utilization of biocrust technology was unquestionably sustainable, with broad application prospects and advantages, as its successful application in more than 40 km^2 desert region in China, and applications in different geographical regions of continents evidented.

Wanga, Tiana, Liua et al. (2017) studied on the effects of increasing anthropogenically active nitrogen (N) deposition on soil organic carbon (SOC) decomposition, and consequently affecting SOC storage in terrestrial ecosystems, considering its specific influence might depend on the different types of N deposition and soil nematodes. They wanted to investigate the interrelationship between N deposition and soil nematodes and SOC cycle process in a temperate forest, and evaluated the effects of different types of N deposition on SOC decomposition under the conditions of applying nematocide against control parcels. They concluded that anthropogenic atmospheric N deposition favored the increase of C stocks in soil by reducing the SOC loss, and N types should be considered during assessment of N deposition effects on soil C cycle processes, referring to literature reporting anthropogenically reactive nitrogen (N) deposition in the terrestrial ecosystems had increased more than 300 % in 20th century and would continue to increase, particularly in China. Widespread effects, such as soil biodiversity loss and alteration of SOC decomposition to be important, as the literature they referred showed that the SOC amount in terrestrial ecosystems was more than thrice the amount of atmospheric C.

3.AN INCONVENIENT QUESTION: WHAT IF WE’RE THINKING ABOUT AGRICULTURE ALL WRONG?

This question was asked by Hay (2020) depending on the successful realization of the Project called “New Forest Farm”, which was started at 100 acres of spent field by Mark Shephard in 1994, the author of the book titled “Restoration Agriculture, Real World Permaculture for Farmers” published in 2013. She told that Shepard combined permaculture, information and design intensive technique, which will be described below, and habitat restoration with the goal of using nut trees and animals to produce staple foods. In short, she told that Shepard had begun by researching biomes, large, natural communities of distinctive biota, and discovered the widest one, savana, a grassy area scattered with shrubs and trees, and the most common type, the oak savana, which was composed of tall, nut-bearing trees, oaks, chestnuts, and beeches, apples, hazelnuts, cherries, plums, peaches, raspberries and blackberries, gooseberries and currants, grapes, grasses, and certainly microbiota. Shepard had decided to found a farm mimicking an oak savana grow annual grains, he decided, he would design a farm that mimicked the oak savanna, with nuts and meats as staple foods, and planted thousands of shrubs and trees. He had converted the former row-crop grain fields into a wild yet organized landscape: curving lines of mixed chestnuts, walnuts, hazelnuts, apples, and elderberries alternating with alleys of grass grazed by cattle, pigs, sheep, andpoultry.

Actually, mycologist Howard (1921) introduced his approach to agriculture in the book titled as 'An Agricultural Testament'; he was the first pioneer of the sustainable agriculture method, who studied agriculture at Cambridge University, and expanded his knowledge in practical research and study in the West Indies, India, and England, where natural agriculture was practiced. His 26 years long vast experience at the field as a mycologist proved the value of soil biota in agriculture. He tried to find an answer to the problem in his mind, "Can mankind regulate its affairs so that its chief possession - the fertility of the soil - is preserved? He realized the fact that forests manured themselves,. the native Indian peasants, who had the healthiest crops and animals were those who were not using chemical fertilizers, and succeeded to be the Pioneer of organic agriculture. Dr. Rudolf Steiner introduced 'biodynamic, biological dynamic agriculture' practice in Poland in 1924 (Paull, 2011), and Müeller and Rusch introduced minimal input using 'Closed System Agriculture' at thirtees (Food and Agriculture Organization, 2014) and Howard (1921) titled as 'An Agricultural Testament', which is considered as the milestone of modern organic agriculture. Zonis (2006) wrote an article titled "Organic versus Biodynamic Agriculture Organic Matter" and compared these practices for the enthusiast audiences; if summarized very briefly here, while organic agriculturists were focusing on the increase of plant nutrient supply by the soil biota, biodynamic agriculturists accepted soil as a dynamic, living organism, as they handle their agricultural ecosystem, and tried to align their activities with circadien rhythm of the plants they grew. Thus, they accepted organic agriculture as it was, and criticised the practice as a mechanical approach, neglecting most of the natural needs of organisms. Actually, Zonis (2006) also drew attention to the Howard's view on the relationship between health of humankind and animals, plants in his book, which depended on his observations of infection resistant livestock when they were fed by grasses grown on fertile soil in the field. Howard, in fact, described healthy, fertile soil in terms of high level of natural organic matter supporting greater diversity of soil organisms, from useful bacteria, to mycorrhizal fungi to earthworms, as the very well known and generally accepted fact nowadays (Delgado-Baquerizo, et al. 2017). Howard utilized the methods of cross-fertilization, conscious irrigation, mycorrhizal symbiosis, soil drainage and aeration, fruit tree growing, weed control and integral health protection (Zonis, 2006). bu ileri görüşlülüğünün kendisine saygı gösterilmesi yanında ekstremist damgasının vurulmasına da neden olduğunu bildirmektedir. Heckman, J. (2006) shared the description of Howard in his book titled The War in the Soil, that can be summarized as the conflict between the rights of humanity to have healthy food from the healthy soil and the capital investors and their organizations selling chemical fertilizers and agricultural chemicals. It is worth to mention here that, Sprengel-Liebig minimum law, stating that growth is dictated not by total resources available, but by the scarcest resource, limiting factor was accepted and practiced widely by plant nutritionists (Reilly, and Fuglie, 1998), but importance of recycling was neglected, depending on the promising developments in chemical and mechanical Technologies, which were named as 'green revolution' for a long period (Pingali, 2012).

A recent review on the topic, covering comparisons for the enthusiasts was published by Dhiman, V. (2020). It can be worth mentioning very briefly here that, while organic agriculture focuses on protection of consumers' health, biodynamic agriculturists also try to protect, improve and sustain the health of the entire ecosystem, as much as they can. As a matter of fact, there are two independent international organizations of organic and biodynamic

agriculture practitioners, entitled to certify the producers; Demeter Biodynamic Assoc. (https://www.biodynamics.com) and IFOAM Organics Assoc. (https://www.ifoam.bio).
Whitney, C (2013) on the other hand, compared biodynamic agriculture with permaculture, literally permanent agriculture, who described it as a philosophy-design farming and living method that grew out of the books and courses of Australian farmers and researchers, B. Mollison and D. Holmgren. Permaculture systems were modeled ones on some patterns observed in nature; structures, access and water systems were also energy efficient and placed as an element of the system rather than a simple, individual component to be fixed. He referred to Holmgren's description, "Traditional agriculture was labour intensive, industrial agriculture is energy intensive, and permaculture-designed systems are information and design intensive", and added that permaculturists were expected to spend most of their time and energy for planning the farming system, in turn to pay less and less attention for its maintenance. Permaculture was not expected to have an unconditional ecological, organic or biodynamic perspective; so, there were not legal limits and regulations. It is worth to refer to the inconvenient question asked by Hey (2020), and underlying reasons, here, as it is very well known that monocultural intensive agricultural practices lead to destruction of complex ecosystems consisting of annual and perennial, and annuals. She referred to "Special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems" (IPCC, 2020) and regretted that approximately third of the world's ice-free land was cleared by cutting forests down and plowing prairies to create agricultural fields; she added that crop production activities also made 23 % of the total sera gas emissions. The consequences of such impacts of human activities reached to a level that irritated World Health Organization and warn (WHO, 2020). The questions included impacts of land degradation, desertification, loss of arable lands and pastures on food and fresh water supply, malnutrition, atmospheric dust, hygiene, epidemies, air quality, public health.

As described by Hay (2020), the overstory of Mark Shephard's New Forest Farm was composed of tall, nut-bearing trees of *Fagaceae* family, oaks, chestnuts, and beeches, beneath that were apples, hazelnuts, cherries, plums, peaches, raspberries and blackberries, gooseberries and currants, grapes, grasses, mushrooms and other plants populated the oak savannas, excluding the edible annual grains, in order to mimic the oak savanna with nuts and meats as staple foods by planting thousands of shrubs and trees, to convert the former row-crop grain fields into a wild yet organized landscape by curving lines of trees and shrubs alternating with alleys of annuals grazed by livestock and poultry. She reminds that the people of northern Italy have long relied on chestnuts and they named them as "the bread tree", distribution of tree crops like honey locusts in North America had been linked to former indigenous village sites, where botanist W. Bartram recorded extensive cultivation of tree crops, in particular, hickory nuts, by Native American tribes in what is now the southeastern U.S. She added that, the U.S. government leaned heavily on trees for relief, planting some 220 million trees on the Great Plains between Canada and Texas in an effort to curb erosion During the Dust Bowl years. As part of the New Deal, FDR started programs in agricultural areas like Tennessee — degraded by decades of cotton, corn, and tobacco — to restore the land with millions of tree crop seedlings. Hay (2020) also reminded that Columbia University professor J. Russell Smith, studied agriculture at home and around the world, called the cereals as weaklings, and tree crop as a permanent agriculture, considering their yearly production ability. She gave some more examples of assessment of edible and other economical tree products from some other countries, such as Greece.

Papanastasis, K., Mantzanas, O., Dini-Papanastasi, et al (2014) exemplified that agroforestry systems were a traditional land use practice in Greece, that were widely distributed all over and constituted important elements of the rural landscape; three types of systems were present, silvoarable on arable land, silvopastoral involving trees and pasture/animals grown on forest and arable land, agrosilvopastoral on arable land with trees, crops and grazing animals. Natural or planted, evergreen or deciduous forest trees, cultivated fruit trees, annual or perennial crops and sheep, goats, cattle, pigs or poultry were present in the systems covering approximately more than 3 million ha., 23% of the country. All systems were delivering a great variety of goods and services for a considerably long period of the year in a sustainable manner, also by improving the environment. Despite these benefits and importance, the systems have been degraded over the last few decades due to extensification/intensification processes imposed by socio-economic changes. Thus, Papanastasis et al (2014) attempted to analyse their economic, ecological and cultural roles, discussed their recent evolution and made recommendations for their inventory, conservation and sustainable management.

In an article titled Agroforestry, Food and Agriculture Organization-FAO (2020) summarized the traditional and modern agroforestry concepts and analyzed the differences between them. It was said that although there was great regional differences, the practice of maintaining or integrating trees in the agricultural landscape had a long history in land use management, from ancient times to the present. In Europe, the the history of Spanish 'Dehesas', of a system in which pasture for cattle, swine, sheep covered by scattered oaks was said to have its origins dating back 4 500 years. In the Americas, numerous communities practiced multi-story agriculture mimicking complex forest ecosystems during the pre-Columbian period in order to enjoy their multiple benefits, which are also the economical expectations nowadays. The Indian Peninsula was given as the example of agroforestry practices in Asia, with its traditional millenial homegardens; some of them with specific systems had received support from the rulers. It was added that in Africa trees traditionally covered ground crops, Swidden cultivation, also known as shifting cultivation, was stil widely used and one of the first agricultural techniques ever developed. Atangana, Khasa, Chang, et al. (2014), in fact, acknowledged the lack of interest in tropical agroforestry, and presented comprehensive data and information on the agroforestry in a 375 pages book, which was covering information from tropical bioms to biological nitrogen fixation and mycorrhizal associations in agroforestry, agroforestry for soil conservation, integrated pest management in tropical agroforestry, several other topics and and finally agroforestry modelling. They considered the increasing interest in carbon sequestration, mitigation of climate change and reducing emissions from deforestation and forest degradation, including conservation and sustainable management of forests and the enhancement of forest carbon stocks mechanisms. Smith, J. (2010) on the other hand, interested in the history of temperate zone agroforestry.

The term agroforestry has been used since seventees, as one of the alternative approaches to solve growing environmental problems, and high number of national, international organizations founded, finally in 2018 world's leading forestry and agroforestry organizations merged for accelerated impact against climate change (Center for International Forestry Research - CIFOR, 2018). As a matter of fact, IPCC (2019) considered agroforestry as an essential practice for sustainable land use and a solution to global warming, and EU immediately expressed its support to this consideration through European Agroforestry Federation (Euraf, 2019).

Aschi, A., Aubert M , Riah-Anglet, W. et al. (2017) presented a study on the crop rotation by using legumes to observe the benefits regarding the structure and function of soil microbial communities, and designed an experiment by Wheat-Beet-Faba Bean-Rape-Wheat (Leg+) and Wheat-Flax-Wheat-Beet-Wheat (Leg−) rotations. Soil samples were collected and analyzed for Soil microbial biomass and soil enzymatic activities (β-glucosidase, cellulase, urease and arylamidase activities) were assessed. Soil microbial diversity was evaluated with two complementary approaches: Phospholipid fatty acid profiling (PLFA) and the metabolic capabilities. They found that soil organic carbon and total nitrogen were significantly and respectively 1.5 and 1.3 times higher in faba bean's rotation. Soil microbial biomass did not differ significantly, but Legume+ rotation resulted in the greatest carbon mineralization and β-glucosidase and arylamidase activities, modified microbial populations and induced differences in the catabolic capability of soil microbial communities, modified the surrounding habitat of microbial communities by providing available carbon and nitrogen as well as suitable soil pH.

They mentioned the presence of numerous studies on innovative practices that had emerged to reduce the impact of agriculture on climate and environment changes with a focus of scientists on the way crop rotation can be designed to contribute to weed control and decrease in diseases and pest attacks, selection of plant spp. in rotation also for increasing the soil water holding capacity by reducing soil erosion, contribution to the amount and quality of organic matter entering the soil. They added that according to the spp. selected, the mineralization of residues could release important quantity of nutrients maintaining soil fertility. Such benefits of biodiversity can be obtained by using agroforestry systems by selection of Mimosoidae trees and shrubs, which are very well known to include numerous native desert spp. (Panwar, Tak and Gehlot, 2014)

4. AGROFORESTRY AND WATER ECONOMY

Malik, Oroan, Kumar et al. (2019) described the functions of trees in agroforestry systems as fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition; fodder trees for livestock; timber and energy trees for shelter and fuel wood; medicinal trees to cure diseases and trees for minor products viz. gums, resins or latex products, and added that many of these trees were multipurpose ones, providing a range of benefits. They presented the area of estimated total green cover in the agroforestry system of India as 111,554 km^2, 3.39 % of geographical area, which would be doubled and supported according to The National Agroforestry Policy announced in 2014, in order to reduce poverty in rural India, where the gap of demand and supply of forest products was widening and forests were unable to fulfill the demand. Agroforestry was also expected to play an important role in filling this gap and conservation of natural resources including water, and also offer a considerable contribution to food supply.

They reminded that agriculture was the largest single user of fresh water, accounting for 75% of current human water use, and 7% of the world’s population were living in areas where water was scarce, and predictions were indicating a rise to a staggering 67% of the population by 2050, while arable land would also be declined by erosion, desertification and other developments. Their conclusion was the future increases in production would have to come from higher productivitysupported by higher water use efficiency. They added that irrigated and rainfed agriculture was using only 10–30% of the available water for plant growth, and in arid and semi-arid areas it was only 5% or so in rainfed crops. This picture could be improved by using the potential of higher water use efficiency of agroforestry, if the very low level of awareness regarding the water management in agroforestry systems. There was, therefore, great potential for improving water use efficiency in agroforestry, particularly, in those areas where the need was greatest in this world's first country adopted a comprehensive agroforestry policy.

Gomes, L.C., Bianchi F.J.J.A., Cardoso I.M., et al. (2020) also considered the severe impacts of global warming and analyzed the effect of projected changes in 2050 on the major coffee production area of Brasil. One of the intended areas of the study was the potential of agroforestry systems to mitigate the projected effects in the region, by comparing the results calculated for unshaded plantations and in agroforestry systems. The climate models they used included the changes in substantial increases in the temperature and changes in precipitation regimes indicated that the annual mean air temperature is expected to increase 1.7 °C±0.3 and considerable decrease of precipitation in the study region, which would lead to almost 60 % reduction in coffee production in unshaded plantations by 2050. 50 % shade cover by the trees of the agroforestry systems could still maintain 75 % of the area suitable for coffee production in 2050, by reducing the mean temperatures and nature conservation.

Hatfield and Dold (2019) reviewed the literature on the definition of water-use efficiency (WUE) and the related advances and challenges with it in the global warming era; they also included agroforestry practices in their brilliant article. They tried to find an answer to the question, if WUE was defined as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop, how plants would respond to changes in environmental factors affecting their WUE at stress levels, as the response was directly related to the physiological processes controlling the gradients of CO_2 and water in the leaf. There a variety of methods available to screen genetic material for enhanced WUE under scenarios of climate change. At canopy level the dynamics of crop water use and biomass accumulation should be related to soil water retention and evaporation rate, transpiration from the leaves, and the growth pattern of the crop. They added that enhancing WUE at that level could be achieved practices increasing soil moisture retention reducing the soil water evaporation, and diverting more water into transpiration by crop residue management, mulching, row spacing, and irrigation, in addition to crop selection. As well known and summarized by them selection of annuals and herbacious perennials depend on the factors such as their photosynthesis type, phenological properties, leaf morphology, root system, growth season, volatile chemicals emissions etc., with the exception of photosynthesis types, same criteria can be used for the woody perennials. They also mentioned that, each plant species had a unique arrangement of a set of single leaves and arrangement of canopies affecting the exposure of their leaves to solar radiation, so photosynthesis and dry matter production of annuals were varying wıthin the growing season, while such changes throughout the growing season were not that large at the canopy of woody spp. Although there was a direct relationship to WUE and increasing CO_2 increase at leaf scale, the direct relationships between WUE and changes in climate parameters were less obvious and often not detectable, thus quantification of the accumulation of dry matter and water used by the in growth season was needed. They referred to several articles presenting the methods used for this purpose.

On the expected increase in CO_2 over the remainder of this century, they stated that the effect would be a decrease in transpiration which would have a positive impact on plant water use efficiency. Increasing temperature, on the other hand, would stimulate the rate of growth and, especially reproductive development and water use, the net result would be shortened period of vegetative growth, smaller leaf area and reduction of the seasonal water use. A shift toward crops with a longer growing season or perennial crops would increase the seasonal crop water use because of the longer leaf area duration. After summarizing the results of previous experiments obtained on different crops by other researchers, they concluded that increasing CO_2 at moderate temperatures increased WUE; however, the positive effect diminished with the temperature increases above the optimum temperature for the species. There were offsetting effects between canopy temperature increase stimulated by increasing air temperature and larger leaf area, which kept the changes in evapotranspiration (ET) small. Referring to a study taking the feedbacks between transpiration and leaf temperature under changing CO_2 for a soybean growth model, they presented ET data showing seasonal decrease under irrigated and rainfed conditions. They added that simulated WUE showed an increase, which was attributed to prolonged use of soil water in the rainfed environments. They concluded that there was a need to understand the interactions of soil water, CO_2, and temperature during the growing season in order to develop more effective management strategies to cope with the changing climate.

Another important topic covered by Hatfield and Dold (2019) was the effect of the changes in solar radiation, 'solar dimming', caused by particles and aerosols accumulated in the atmosphere, which was often overlooked, but affecting the photosynthetically active radiation, (PAR) and consequently gross photosynthetic production (GPP), which is a function of the PAR absorbed by the canopy (APAR) and the capacity of utilization of the photosynthetic products. Low frequency (day-to-day) variation in GPP is associated with crop phenological stage and physiological status. They presented literature showing that changes in the solar radiation regime would affect photosynthesis and GPP, WUE, and found that both radiation use efficiency (RUE) and WUE decreased linearly with increasing direct PAR; in another study it was observed that observed that the fluctuating light would increase productivity, because of photoprotection mechanisms, C_4 plants were more sensitive than C_3 plants to fluctuating light conditions. In another study referred, it was showed that changes in canopy architecture would have positive effects on the overall productivity of crops. They concluded that changes in the radiation would increase RUE and WUE because of the more uniform radiation supplied be scattered light on the maize canopy, and . such changes in the solar radiation under climate change needed to be included in evaluations of the effects of temperature and precipitation.

5.EFFECTS OF CROPPING SYSTEM ON WUE

As it was mentioned in above sections, Hatfield and Dold (2019) also interested in and studied on the complex relation between crops, their phenology, physiology, cropping systems and climate, and global warming. They referred to the studies on potato, showing that WUE increased by increasing ambient temperature up to 1.5°C above normal and then began to decrease, it also decreased linearly by increasing annual precipitation over 310 mm. The explanation was the increase in respiration, which was observed and reported before for coniferous trees, thus respiraton rate should be measured and its changes should be included in the future studies on WUE and productivity. They added that impacts of climate change on productivity could be extended beyond the direct impacts on photosynthesis and water use by canopies to the impacts related to changes in cultural practices affecting the respond of canopies to climate variation. They referred to several previous studies on the effects of different practices on WUE, such as seasonal ambient temperature, precipitation, baseline soil fertility, and fertilizer management. Presented results of some previously reported studies on mulching evidented increased WUE and yield considerably by decreasing soil water evaporation especially in semi-arid regions, mulching and micro-dosing of NPK fertilizer increased WUE in low-input agriculture in a semi-arid climate. They also referred to studies on tall fescue and alfalfa, which showed that limiting nitrogen nutrition had a negative effect on WUE by decreasing transpiration/evaporation ratio, and supported the conclusion reached by the authors of the study, interactions between nitrogen status and water deficits should be investigated to improve WUE.

Although irrigation had been considered as the most effective solution to solve the water scarcity and deficit problems, Hatfield and Dold (2019) attracted attention to the fact that, the impact on WUE could be substantial, if the production increase compared to the amount of water used by the crop . They referred to a previous report presenting the results of a meta-analysis on 49 experiments of irrigated wheat and cotton throughout China under furrow and micro-irrigation systems, to determine the optimum water use level to achieve maximum WUE. They said that, water use by wheat could be reduced by 30% at the cost of grain yield loss of 15%; however, in cotton 51% drop in water consumption was caused a 52% yield reduction. Micro-irrigation reduced wheat water use by 23% and increased yield by 37%, but in cotton water use dropped 37% and yield was 21% less. Micro-irrigation reduced evaporation early in the season and limited almost all the evaporation from the surfaces of the leaves and increased WUE, as expected.

Another factor should be manipulation of row spacing which would affect evaporation/transpiration ratio, narrow rows would decrease evaporation and increase WUE, but the previously reported experimental study on maize increased WUE only 17% if nitrogen nutrition and water were limited. The conclusion was an increase in WUE in water limited, variable rainfall conditions. In another previous study simulation models used and reduction of row width was recommended as an effective strategy in rainfed production, especially for the regions where soil water evaporation loss were high, in areas with clay soils with frequent rain events and low atmospheric demand.

Another adaptive strategy to increase WUE, diversifying the crop rotation to increase the resilience of the overall cropping system was also reviewed by Hatfield and Dold (2019). The referred studies compared different rotations to determine if adding them would increase WUE and crop production than the monocultures, and rainfall variation among growing seasons was found to be the main determinate of water use and WUE. The conclusion was that intercropping system would offer advantages for more efficient water use in water-limited environments, as mentioned above for agroforestry systems.

Finally Hatfield and Dold (2019) referred to some articles on the increase of WUE levels over time by releasing new hybrids offering higher WUE at various soil water contents on the basis of product quantity, reflecting higher assimilation rates under temperature and water-deficit stress.

6.CONCLUSION

Climate is a complex phenomenon, soil has a complex structure and texture, soil biota also comprises an enormous diversity of organisms, any changes in their delicate equilibria are also reflected to flora and fauna, consequent changes in flora and fauna lead to dramatic changes in the other components of the ecosystems. Solving the concurrent problems considering the future ones desperately need integral approaches by interdisciplinary groups of specialists. It is well known that biodiversity and physiodiversity, functional diversity boost ecosystem stability, productivity, where each species, has an important role to play, a larger number of plant species increase the resilience, sustainability of the ecosystem. Healthy ecosystems can better withstand and recover from a variety of disasters. All of the specialists need to appreciate the value of interdisciplinary approaches to the environmental problems, people and decision makers have to be convinced that Einstein was right in saying "We cannot solve our problems with the same thinking we used when we created them", they must see that climate change and other environmental problems cannot be solved by the same paradigm.

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