Sustainable Agriculture Water Management in a Changing Environment: A Special Focus on Olive Tree

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SUSTAINABLE AGRICULTURE WATER MANAGEMENT IN A CHANGING ENVIRONMENT: A SPECIAL FOCUS ON OLIVE TREE

International Training Workshop

Organized
by

Department of Environmental Sciences
Faculty of Forestry, Range Management & Wildlife
PMAS-Arid Agriculture University Rawalpindi, Pakistan

In collaboration with

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&
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SUSTAINABLE AGRICULTURE WATER MANAGEMENT IN A CHANGING ENVIRONMENT: A SPECIAL FOCUS ON OLIVE TREE

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Held at Pir Mehr Ali Shah (PMAS) Arid Agriculture University, Rawalpindi, Pakistan

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Dr. Azeem Khalid
Organizing Secretary

Preface

The global environment is changing with increasing temperature and CO_2. These are key variables which affect plant growth, development and functions. Moreover, the combination of elevated temperatures and the increased incidence of environmental stresses will probably constitute the greatest risk caused by global climate change to agricultural ecosystems in arid and semiarid areas of the world. Arid and semiarid lands are characterized by low and highly variable rainfall, and inter-annual variability in the total annual precipitation.In addition, the onset of rainy season is unpredictable and the length of the “dry season” varies from year to year. All these factors strongly limit primary productivity. Thus, it is necessary to learn as much details as possible on how agricultural ecosystems are and will be affected by the predicted environmental changes. The ability to capitalise on the beneficial effects of global change, while avoiding or reducing adverse effects, will require a strong predictive capability.

Pakistan is one of the countries, which is most vulnerable to climate change and environmental stresses. Therefore,it is an urgent need to adapt and promote techniques that, without requiring large infrastructures and investments, could counteract environmental stresses, water shortage and land degradation, leading to a recovery of crop productivity. Innovative water management techniques that can mitigate the impact of different environmental factors on agricultural production are currently available. It is essential that these systems of water management in agriculture should be sustainable.

Olive is the most economically important oil tree crop in temperate areas, with 10.2 million hectares under cultivation (FAO, 2012), and one of the most social and historically important crops in the Mediterranean Basin and ends in Pakistan. Olive has been traditionally a rainfed crop, but there has been a large increase in the amount of irrigation water used in olive farming, promoted by spectacular increases in yield. However, most olive production is located in regions where water is very scarce, even for human use. Therefore, the economy of these regions is calling for a better management policy. Pakistan has an immense potential for olive cultivation. Millions of wild olive plants already exist in various areas of Pakistan because of having most suitable conditions to cultivate finest nest olive varieties. Recent expert survey has identified 890,000 hectares potential suitable area for production. However, the weakness of the education system, as well as training and technology transfer to promote olive production in Pakistan is the main problem that must be addressed.

Keeping in view the propect of olive cultivation in Pakistan, an international training workshop was organizedin order to demonstrate and disseminate the state-of-the-art knowledge and results developed bythe interactive research on tree crops, with special focus on olive and water. In addition, innovative management strategies and characterization of olive genetic resources to enhance the conservation and sustainable use and ensure the future of this crop in different climate change scenarios are also discussed in the conference.

Azeem Khalid

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Welcome Address
by
Prof. Dr. Rai Niaz Ahmad
Vice Chancellor
PMAS-Arid Agriculture University Rawalpindi, Pakistan

It is a matter of gratification and pleasure for me to welcome you all here on this august occasion of opening ceremony of international training workshop on "Sustainable Agriculture Water Management in a Changing Environment – A Special Focus on Olive Tree". It is delightful and honor for me to welcome Honorable Federal Minister forPlanning, Development & Reforms,Professor Ahsan Iqbal, who very graciously consented to be the Chief Guest of today's ceremony.

I am grateful to our international delegates from Italy, Greece and Tunisia who came a long way to share their valuable knowledge and experiences in the field of water management with special reference to olive cultivation in changing climatic conditions around the globe. I am confident that with international collaboration we will be achieving the goal of promoting olive cultivation in Pakistan, which is a long awaited dream of this country spending billions of dollars on the import of edible oil from different countries.

Ladies & Gentlemen!

Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi realizing the significance of interactive learning pays special attention in arranging workshops, seminars and scientific gatherings for provision of enabling environment to the scientific community to share their valuable knowledge and experiences for advancement of science and technology and undertake output oriented endeavors to combat the devastating impact of climate change on agricultural production and ensure food security for masses at large.

Honorable Federal Minister Sir,

We are thankful for your presence and let me share that Pothwar region being at the lower web of economy needs special attention for its uplifting and resultant contribution to GDP of the country. Pothwar is characterized with scanty rains, sloping lands barefooted shepherds honking their flocks. Modern agriculture is need of the day for this region especially to meet the water shortage with practices like harvesting of rainwater and its efficient use for sustainable agriculture.

To harness the optimum dividends from Pothwar region, there is a dire need of paradigm shift from growing conventional crops to exotic varieties of vegetable and orchard farming with special emphasis on high value crops.

Honorable Minister Sir,

It is elating me to share that Pothwar has recently been declared as "**Olive Valley"**. It is further exciting that this declaration of Pothwar as Olive Valley has its roots back in this University where primarily, this idea of declaring Pothwar as Valey of Olive and Vegetables was floated in front of Federal Minister for Planning, Development & Reforms here in this auditorium on the eve of international seminar on Korea's New Village Movement and Economic Development back in 2013.

Significance of olive can be revealed as it has been mentioned seven times in the Holy Quran. I will only quote, where we find integrated approach which covers the entire agricultural cycle.

> "Allah is the one who sends water down from the sky therewith we brought forth plants of all kinds and from them the verdure and we brought forth from it the clustered grains, and from the palm trees its spathes with bunches of dates, the gardens of grapes, olive and pomegranates, similar and different look at their fruit when they bear it and their ripening, variety in that their signs for people who believe (Quran 6:99)

Further, the importance of olive is elaborated by our Prophet Muhammad (may the peace and blessings of Allah be upon him) narrated by Hazrath Abu Hurairah:

> "Eat the olive oil and apply it (locally), since there is cure for seventy diseases in it, one of them is Leprosy" (Abu Naim).

Why this workshop is planned on the theme of sustainable water management and the olive? Olive tree has a very interesting characteristic of having its extensive underground roots system that can go above twenty feet deep in soil, so

under water stress environment when most of the trees die, it can survive and continue fruiting for hundreds of years. It has been said that olive draw water from heavens and bear fruit even after the tree looks as if there is no life left in it.

Ladies & Gentlemen!

Pothwar region by nature has enormous potential for olive production as it has already millions wild olive plants. This Pothwar region of Punjab alone has the world's largest potential area (3.2 million hectares) for olive production. However, question to all of us for its fruit production. Estimates have shown that if 8 million wild olive trees present in different provinces are converted into productive olives, then there is a potential of earning one billion dollars annually.

Honorable Minister Sir,

Here I should openly accept and acknowledge that being agriculture scientist myself as well as having a massive agriculture research infrastructure in the country we did not pay due attention in the past towards this blessing. Time has come for extensive efforts to convert import of edible oil to export of olive oil. Pir Mehr Ali Shah Arid Agriculture University Rawalpindi is coming with silent revolution on propagation and mass multiplication of olive through various projects. We are also a part of mega project initiated recently sanctioned by the Government to promote olive production in Pakistan, particularly in Pothwar region. The University is also engaged in producing olive nurseries through tissue culture techniques in our labs at campus besides the conventional methods. I would submit that other universities and R&D organizations should also come forward and replicate the tissue culture techniques and other models being developed at this campus for promotion of olive gardening in the country, on war footings.

Ensuring food security and key to success especially in high value crops like olive, fruits and vegetables, I would request your good-self to consider for incorporation of food processing industry in our future agricultural policies.

Ladies & Gentlemen!

I once again thank our today's Chief Guest, Guest of Honor and learned resource persons from inland and aboard for their valuable presence here at campus. Let me also acknowledge and appreciate efforts of the Department of Environmental Sciences to organize this international event and our partners from CNR Italy for their contribution in the past as well as in future to promote agriculture, especially high value crop in the country.

Thank you All and God Bless You

Pakistan Paind'abad

Inaugural Address
by
Professor Ahsan Iqbal
Federal Minister for Planning, Development and Reforms

It's a matter of immense pleasure to be among the eminent scientists and academicians. I thank, Prof. Rai Niaz Ahmad for giving me the opportunity to be part of this gathering and interact with agricultural specialists and our distinguished guests from Italian Embassy and speakers from Italy, Greece, Tunisia and Pakistan. I feel immense pleasure to be invited to address on the eve of the international training workshop on "Sustainable Agriculture Water Management in a Changing Environment with Special Focus on Olive Tree". Climate change and agriculture can't be discussed on separate forums as both of which take place on a global scale. I understand that being agricultural country food security is one of the priority areas for Pakistan and we have to work not only producing food for our growing nation, but also those nations who lacks in agricultural lands.

Let me congratulate here the Vice Chancellor Prof. Rai Niaz Ahmad and his faculty and especially the Department of Environmental Sciences for organizing this training workshop on water and olive. I highly appreciate the efforts of the Arid Agricultur University, Rawalpindi to provide interactive learning platform. Such forums are very constructive in scientific and technological advancements, especially for sustainable promotion of agriculture in changing climatic conditions.

Ladies & Gentlemen!

Undoubtedly, the change in behavior of water resources with changing climate is the most serious question to the sustainability and promotion of agricultural development. It is important to mention that in the 17th Session of the FAO Conference "Water Problems affecting Agriculture Development" was at the top of the agenda. Moreover, people in many countries including Pakistan are deprived of high valued nutritional food. No matter, how much we can do by ourselves at the national level, whether it be research or development, it is never enough. In a spirit of true cooperation, we must join in an action-oriented effort at national and international levels to tackle and solve the problems for sustainable agriculture development. So the presence of experts from Italy, Greece, Tunisia, as well as experts from differentregions of Pakistan can certainly help provide an effective solution to these problems.

Ladies and Gentlemen!

I am glad that this training workshop is being organized on very important aspect, water and olive. Olive is of great interest to the people of Pakistan since it has been referred in noble way at many places in the Holy Quran and its importance has been certified by the Holy Prophet Muhammad (Peace be upon him).

There is a great potential of olive cultivation in Pakistan, especially in Pothwar region. Olive cultivation is most suitable for arid and semi-arid areas because the plants need little water to grow and can also survive under sweltering heat. The government is fully committed in taking every step to ensure food security. It is notable here that the olive was first introduced in Pakistan in 1986 under an Italian project "fruit, vegetables and olive", funded by the Government of Italy. The interest of Italy in promotion of olive cultivation in Pakistan is still continued and this joint effort of organization the training workshop is evidence of this interest.

Let me share some statistics here. Due to high global demand and rising prices for edible oils in the international market, Pakistan last year imported edible oil worth $2.5 billion. The import of edible oil may jump to $4 billion by 2016, if Pakistan fails to increase yield of its own edible oil. At the moment, total domestic consumption of edible oil in Pakistan is around 1.9 million tonnes, out of which 1.3 million tonnes is imported. Precious foreign exchange could be saved if olive cultivation is stepped up in Pakistan and the country begins producing olive oil to help reduce oil imports. So, there is a considerable potential of olive cultivation and its promotion in Pakistan. To exploit the actual potential of olives in Pakistan, developmental alliances across multiple domains are required. In prevailing circumstances, training workshop like this is highly appreciable for the promotion of olive cultivation through provision of scientific knowledge and technological advancements. It is encouraging to know that the University is actively engaged in propagation of olive through tissue culture techniques, I am extremely hopeful that this would supplement the farming community to promote olive cultivation and improve their livelihood.

Dear participants!

Considering the huge potential in economic development, the pace of olive plantation on mass level needs to be enhanced substantially. The recent and advanced knowledge on olive cultivation brought in by our foreign speakers if replicated in Pothwar may bring about large changes in the livelihood of our farmers. We should not only identify the areas of progression in this field, affirmative strides to harness the actual potential are mandatory. I am glad that Arid Agriculture University has carried out successful steps for promotion of olive cultivation and progression in this field. I will take this opportunity and congratulate the Vice Chancellor for his efforts for olive development in Pothwar area.

Once again, I thank the dignitaries and experts from Italy, Greece, Tunisia, Pakistan and Vice Chancellor of Arid Agriculture University and his Team for giving me an opportunity to speak my heart to you all.

Pakistan Painda'abad

Sustainable management of agricultural water resources: From leaf physiology to dryland ecosystem services

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Abstract

Arid and semi-arid lands are characterized by low and highly inter-annual variability in total annual precipitation. Furthermore, the onset of the rainy season is unpredictable and the length of the "dry season" varies from year to year. All these factors strongly limit primary productivity in these areas. Population growth and predicted climate change are expected to further exacerbate this problem. The consequences would be a reduction of usable arable land and land productivity, widespread ecosystem degradation and higher risk of desertification. Drylands cover over 40% of global land area, are home to 2.1 billion people and comprise over 44% of the world's cultivated systems. Approximately 70% of drylands occur in developing countries, where the livelihoods of the populace depend upon the ecosystem services sustained by the land. There is a strong correlation between poverty, development and the health of the land. Drylands constitute the largest biome on our planet and their degradation influences both the climate system and atmospheric composition. Drylands are amongst the most fragile areas of the globe and are inherently vulnerable to the effects of poor resource management. Desertification is considered to be the last stage of persistent land degradation caused by a combination of biophysical and human factors. There is therefore an urgent need to adapt and promote techniques that, without requiring large infrastructure and investments, could counteract land degradation and water shortage, leading to a recovery of crop productivity. Innovative water management techniques that can mitigate the impact of different environmental factors on agricultural production are currently available. It is essential that these systems of water management in agriculture are sustainable.

Key words: Agro-technologies; aridity; climate change; environmental stress; drylands; irrigation; water use efficiency

Introduction

The role of water in food and livelihood security is an issue of major concern in the context of persistent poverty and continued environmental degradation. Water scarcity is increasingly accepted as a major limitation for increasing agricultural production and food security in the 21st century. Currently, more than 8000 km^3yr^{-1} of water are consumed (i.e. evapotranspired on rainfed and irrigated land) to feed the current world population, and an additional c. 5000 km^3yr^{-1} will be required if the population rises to 10 billion in 2050 as reported by IPCC (2014). Currently, most of the 852 million of poor people in the world live in drylands/rain-fed areas in developing countries of Africa and Asia. However, it is estimated that by 2025 one third of the population in developing countries will be facing physical scarcity of water. These areas are the hot-spots of poverty, malnutrition, water scarcity, severe land degradation, and poor physical and financial infrastructure. Current and future climate change is expected to increase the threat of water shortages, further worsening the water-crisis especially in developing countries and threatening livelihoods particularly in arid areas.

The global volume of green water (precipitation stored in the soil) available for food production is almost three times greater than blue water (from rivers, lakes, and aquifers). However, further increases in agricultural water requirements can be expected due to rising incomes and dietary changes towards higher meat consumption. Global climate change and altered incidence of pests, diseases and weeds will also noticeably impact upon future global food production. Crop production is negatively affected by rising temperatures and declines in regional soil moisture. As the availability of fresh water and arable land are approaching their limits this will have severe consequences for productivity. During the last century, the rate of increase in 'blue' water withdrawals for irrigation and other purposes was higher than the growth rate of the world population. Presently, about 16% of the 15 million km^2 of the land surface covered by cropland is equipped for irrigation. Thus a higher efficiency of blue water use is fundamental to not only fulfil future food demand, but also to alleviate the malnutrition of at least 850 million people. However, crucial question are "to what extent will cropland have to be expanded in the future to guarantee sufficient food production for the growing world population, and how the requirements for additional land and water can be minimized through better management of existing cropland".

Increasing demand for domestic and industrial water use is likely to reduce the water available for agriculture, intensifying the need for an improvement in the efficiency of water use for food production. It has been calculated that a 1% increase in crop water productivity would make available make an extra 24 litres a day per head of population,

while a 10% increase would equal current domestic water consumption. Thus, any increase in agricultural water productivity will save a significant amount of water, and increasing availability for other agricultural, industrial and urban uses. In this regard a concerted and coordinated effort is required to improve the water productivity of agriculture, that is the 'crop per drop', including the efficiency of irrigation, improving crop water use efficiency, and improving the productivity of dryland (rain-fed) cropping systems in water-limited environments.

Drylands

A number of studies have highlighted the processes and effects of land degradation on both the sustainability of dryland ecosystems and social systems. However, the convergence of poor land management with climate change (i.e., rising temperatures, enhanced evapotranspiration, increased incidence and magnitude of drought alongside other extreme weather events), unsustainable use of resources and population growth are posing disproportionate threats to the social-ecological systems of drylands around the world. The impacts of these biophysical and socioeconomic factors are becoming more intense and perpetuate the vicious downward spiral of resource degradation and poverty, affecting the world's poorest peoplewho largely depend on natural resources.

Major global concerns are the surge of water-related crises and runaway global warming. New evidence shows that climate change has increased evaporation from water bodies (primarily from seas), and as a consequence accelerated the global hydrological cycle (IPCC, 2014). As global warming proceeds, evaporation from water surfaces will rise due to an increase in the vapour-pressure difference between the Earth's atmosphere and water bodies (the terrestrial atmosphere contains only 0.001% of global water). In turn, this will increase other components of the global hydrological cycle, such as enhanced global annual precipitation, in the form of more intense storms and runoff from the continents into the seas. Altered regional and temporal distribution of precipitation will strongly affect dryland (i.e., arid, semi-arid and dry sub-humid areas) and temperate areas through the reduced availability of water resources.

Combating desertification is becoming one of the major questions facing society today. Isolated interventions are often ineffective and sometimes dangerous; because the combination of natural and anthropogenic (political, social, and economic) factors causing desertification vary over space and time, and may be amplifiedby global warming. To restore the sustainability of degraded dryland ecosystem services, a systemic approach is required at both the local and global levels. An understanding of ecosystem function and resilience under changing environmental conditions is of the utmost importance to improved decision-making and operational activities towards supporting dryland ecological and social systems, the effective design of restoration programs for degraded ecosystems and the development of successful adaptation and mitigation strategies at national and international scales.

Ecosystem approach to combating desertification

As the largest biome on the plant, arid ecosystems play an important role in the regulation of the carbon and water cycles, protect the resources of the soil and affect atmospheric composition through physical, chemical and biological processes. Changes in the structure and functioning of these ecosystems result in alterations to the properties of the Earth's surface and affect the efficiency of the exchange of water, energy and CO_2 between ecosystems and the atmosphere (Bonan, 2008). Due to the higher albedo of deserts than forests and agricultural land, increased desertification over the past 35 years has counteracted global warming to an equivalent of approximately 20% of the radiative forcing caused the increased global emissions of CO_2 occurring during the same period (Rotenberg & Yakir, 2010). At the same time, they have shown that the Yatir forest, a small pine forest planted on the edge of the "dry timberline" perimeter of the Negev desert (285 mm / year of average rainfall) in the south of Israel, after 40 years of growth achieve a balance between the heating effect due to the reduced albedo and the cooling caused by carbon sequestration. The conclusion of the authors is that in a worst case scenario, the time required to achieve a net cooling effect from this type of planting would require around 80 years.

These studies demonstrate the importance of teleconnections between arid ecosystems and the regional and global climate, but also that the key challenge to be faced is the rehabilitation of the areas threatened by desertification processes by the loss of ecosystem services (Millennium Ecosystem Assessment, 2005). About 10-20% of drylands are already affected by desertification. The functioning and resilience of these territories and thus the sustainability of ecosystem services, are increasingly threatened by a number of converging trends that include land degradation, climate change (temperature increase and greater potential evapotranspiration, increased incidence and intensity of droughts and other extreme weather events, etc.) (Centritto *et al*., 2011) and population growth. The impacts of biophysical components, operating at different scales, are becoming more intense and contribute to the vicious circle of resource degradation (Khalid *et al*., 2011). With the intensification of heat waves (Barriopedro *et al*., 2011), the occurrence of mega-droughts (Dai, 2011), many drylands could soon reach the point of no return. A transformation in the processes of desertification (despite having lower rates of biological activity and sparse biota deserts are still ecosystems,) towards the formation of "dust-bowls" that could be irreversible for centuries (Romm, 2011). It is therefore urgent to rethink

dramatic interventions to combat desertification and prevent at the same time also their degeneration into "dust-bowls". An approach based on restoring ecosystem services (Perrings *et al*., 2011) primarily through the hydrological cycle, is necessary to improve the resilience of drylands.

Biodiversity and ecosystem services

There is a close relationship between biodiversity and ecosystem services. Different species of micro- and macro-organisms of biota differ in the method of use and transformation of resources, in their effects on the physical environment and in their interactions with other species. Therefore, any changes in the composition and abundance of species will alter ecosystem processes (particularly those that influence biogeochemical cycles and bio-geotrophic interactions, etc.) through changes in the structural and functional characteristics of those ecosystems. This could affect ecosystem processes sufficiently to alter the services that ecosystems provide to humanity through the purification of water resources, climate regulation, food production, fuel and materials, nutrient cycle, and soil conservation (Millennium Ecosystem Assessment, 2005). The greater the variation in the composition and functional diversity of species, the greater their impact on the functioning of ecosystems and the response of these ecosystems to environmental changes (Chapin III *et al*., 1997).

Recent studies have shown that the loss of biodiversity has already begun to degrade the essential processes that govern the productivity and sustainability of ecosystems on Earth (Hooper *et al*., 2012). Since the functions of ecosystems are positively related to interspecific complementarity, that develop over time and result in a high diversity of species combinations (Reich *et al*., 2012), any further loss of biodiversity will accelerate changes in ecosystem processes. Arid ecosystems account for 20% of the centres of biodiversity and 30% of the endemic birds of the world, and do not escape from this cause-effect correlation between wealth of biodiversity and multifunctionality of ecosystems. Maestre *et al*. (2012) showed, in a study of 224 arid ecosystems that the relationship between the wealth of biodiversity and multifunctionality of ecosystems grows rapidly with the presence of about five species of perennials, and that this relationship is further strengthened by the addition of more species. This is probably caused by mutual benefits arising from mechanisms of self-organization (Solé, 2007): a process of "facilitation" (positive feedback resulting from short range interactions) relations between different species of plants specialized in creating micro-environments that help others species to survive, while minimizing the loss of water (which is the limiting resource). Consequently, "facilitation" between neighbouring plants may act as a mechanism whereby a degraded land can again become a habitat for other species of plant. These studies clearly indicate that not only is the conservation of biodiversity crucial to the mitigation of the negative effects of climate change and desertification in drylands, but that programs of rehabilitation and reclamation of arid lands must be based on reconstitution of a high degree of biodiversity to increase the number and quality of ecosystem functions.

The quality and quantity of ecosystem services are closely related with the degree of complexity of ecosystem functions, which in turn are closely interconnected with the degree of complexity of biodiversity. It is worth repeating that the species composition and their functional diversity mostly influence the functioning of ecosystems, as species differ in their effects on ecosystem processes or in their response to environmental changes. Contrasting environmental adaptation amongst functionally similar species confers stability to ecosystem processes, while different sensitivities between functionally different species results in ecosystems that are more vulnerable to climatic and environmental changes (Chapin III *et al*., 1997). It is interesting to observe how the multifunctionality of ecosystems has been assessed in terms of the ability to maintain multiple functions, such as increasing the conversion of solar energy, absorption and storage of carbon, converting water into biomass (primary productivity net), soil fertility and nutrient cycling. This set of functions is vital for the rehabilitation of desert areas, but in the absence of a positive impact on the local and regional hydrological cycle these ecosystem functions cannot guarantee the sustainability and resilience of ecosystems. It is therefore important to note that studies on the correlation between biodiversity and ecosystem function, including those on arid ecosystems (Maestre *et al*., 2012), have ignored this aspect that is nullified both in combating desertification and in mitigating climate change.

Biotic pump and the theory of complementarity

It is well known that evapotranspiration plays an important role in the hydrological cycle as a climate feedback (Bonan, 2008; Betts, 2011). In a recent study, its impact was quantified in terms of climate regulation. Anderson-Teixeira *et al*. (2012) have proposed a metric that considers not only the influence biogeochemistry (carbon cycle) ecosystems on the climate, but also converting these effects into biogeochemical units (equivalent CO_2) to facilitate quantitative comparison. However, it does not take into account the impact of ecosystems on the hydrologic cycle. Since arid ecosystems are characterized by the severe conditions imposed by the limited availability of water, the problem remains that the rehabilitation of arid lands concerns the ability of the vegetation to reactivate the local and regional hydrological cycle: in essence, “can the greening of arid lands / desert reactivate the hydrological cycle, thereby contributing to increased rainfall and then cooling to achieve a sustainable local and regional climate?”This is

the fundamental question that research must strive to address. An established theoryregarding the complementary relationship between the potential evapotranspiration (ETP) and the actual evapotranspiration (ETa) (Bouchet, 1963), and the new and compelling theory of a biotic pump (Fig. 1) induced by vegetation (Makarieva & Gorshkov, 2007), may provide an interesting framework for research in this field.

The hypothesis of a complementary relationship between ETP and ETa (Bouchet, 1963) argues that in the absence of a strong environmental disturbance and assuming constant energy supply there is a complementary mechanism of feedback between ETP and Eta over regional scalesWhen the availability of water becomes limiting, the ETa falls below the ETP, and when energy input is constant this results in an excess of energy in the form of sensible heat and / or long-wave radiation, which increases air temperature and in turn leads to an increase of the ETP in the same order of magnitude of reduction of the ETP. In the face of an increased availability of water, the reverse process occurs: the ETa increases and the ETP decreases. As water availability increases, the two evapotranspiration parameters converge towards one another to produce a humid environment (ETW): ETP = ETa = ETW. Then the ETP ceases to be an independent cause (a climatological function) as it is linked to the prevailing moisture availability.

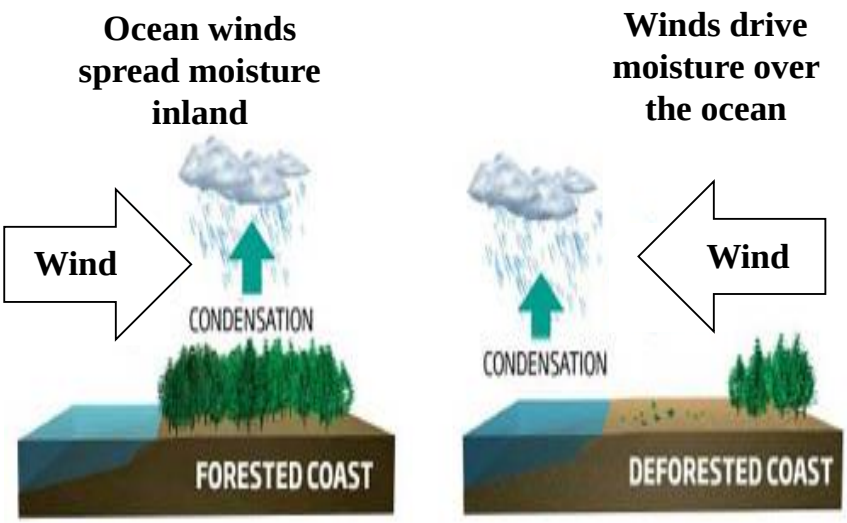

Figure 1. Pump biotic created by the forests that push moisture over thousands of kilometers inland (Makarieva and Gorshkov, 2007). Source: New Scientist, 2009

The possibility of a convergence in arid areas of the ETP and ETW, following involves not only a cooling effect of the regional climate, as demonstrated in the case of the forest Yatir (Rotenberg & Yakir, 2010), but also an increase of the local and regional rainfall. This implies that forests can recycle the rain. For example, approximately half of the precipitation that falls on a tropical rainforest is produced by transpiring trees. This helps to maintain the moist air above the forest resulting in a greater ETa and a lower ETP. Sea winds can spread the moisture inland creating more rainfall. The biotic pump theory claims that forests can create winds that pump moisture within continents (Makarieva & Gorshkov, 2007). The primary mechanism of the biotic pump is generatedby the coastal forests: since the amount of water vapor evapotranspiration from these forests is greater than the amount evaporated from the sea, it leads to a more rapid condensation resulting in low pressure over the forests. This low pressure is replaced by moist air from the sea, thus facilitating the transport of moisture thousands of kilometers within continents. In the case of coastal deforestation, the exact opposite would happen. Despite the biotic pump being predominantly activated by coastal forests, similar mechanisms may operate in mountainous areas and in all conditions that trigger the circulatory movements of air. Furthermore, irrigation systems, introducing water into the system, have a positive climate regulation (Anderson-Teixeira *et al*., 2012), contributing to the convergence between the ETa and ETW, and can play an important role in driving the pump biotic. The primary goal remains the assessment and rehabilitation of arid lands / deserts, through programs of replanting, natural irrigation and by creating extensive forests from the coast, which can contribute to the restoration of the hydrological cycle.

Dry agriculture

Globally 70% of the agricultural land is rain-fed, and it contributes about 62% to the global food production. Thus, rain-fed agriculture plays a crucial role in achieving food security. The challenges of poverty and food security with looming water scarcity cannot be met by irrigated agriculture alone, and major gains have to come through upgrading rain-fed agriculture, as recently shown by the comprehensive assessment of water management in agriculture. By upgrading rainifed agriculture in arid and semi-arid areas, the efficiency of green water for food

production can be substantially increased and pressure on blue water for food production can be reduced. However, in arid and semi-arid areas, rainfall distribution and poor management aggravates water scarcity for crops, resulting in low rainwater use efficiency. Rainwater largely escapes from the soils to atmosphere through unproductive evaporation. Large water productivity gains could be achieved in rain-fed areas by changing vapour flows through productive evapotranspiration (i.e. green water). This requires developing appropriate strategies that ensure augmentation of water resources through rainwater conservation and harvesting as well as improved farming systems.

It is evident that water-scarce countries are not able to meet their food requirements using the water resources available within their boundaries. Maximizing water productivity, and not yield per unit of land, is therefore a better strategy for farming systems in areas of water scarcity. Agronomic increases in crop production may arise from early sowing enabled by minimum tillage, increased fertiliser use (especially nitrogen), weed control, and crop rotations to improve weed control, minimise disease risk, and increase nitrogen availability. Analysts suggest that at least half of the increase in rainfall-use efficiency can be attributed to improved agronomic management. Most of the agronomic options for improving water use efficiency in rain-fed agricultural systems decrease water losses by soil evaporation, runoff, through-flow, deep drainage, and competing weeds, thereby making more water available for the crop. For instance, in arid-type environments, 30-60% of the evapotranspiration of wheat may be lost as evaporation from the soil surface. If the evaporative component of total evapotranspiration could be transpired, growth and water-use efficiency of crops could be increased. Early sowing, increased fertilizer input, planting density and reduced row width which increase early growth have been shown to decrease the evaporation fraction of evapotranspiration. The adoption of agronomic procedures such as those mentioned, in conjunction with new cultivars, has the potential to increase yield and rainfall use efficiency of dryland crops. Genotypic increases in productivity may arise from selection for early vigor, deep roots, increased transpiration efficiency, improved disease resistance, and high assimilate storage and remobilization. Matching a crop's phenology to its environment is the most important determinant of a well-managed crops' water economy.

In areas of water scarcity, the major need for development of irrigation is to minimize water use. Effort is needed to find economic crops using minimal water, to use application methods that minimize the loss of water by evaporation from the soil or percolation of water beyond the depth of root-zone and to minimize losses of water from storage or delivery systems. During the current period of dramatic changes and water resources uncertainty, there is a need to provide support and encouragement to farmers to move from their traditional high-water demand cropping and irrigation practices to modern, reduced demand systems and technologies. Water demand management has paid most attention to irrigation scheduling (when to irrigate and how much water to apply), and given minor roles to irrigation methods (how to apply the water in the field). Many parameters like crop growth stage and its sensitivity to water stress, climatic conditions and water availability in the soil determine when to irrigate or the so-called irrigation frequency. However, this frequency depends upon the irrigation method and therefore, both irrigation scheduling and the irrigation method are inter-related.

Improvements in localized irrigation systems, aiming to reduce the volume of water applied and increase the water productivity, include: a) the use of micro-sprayers in high infiltration soils, b) the adjustment of the duration of water application and timing to soil and crop characteristics, c) the use of appropriate filters to the water quality and the emitter characteristics used, d) the adoption of careful maintenance, automation, fertigation (efficient fertilizer application) and chemigation (easy control of weeds and soil born diseases). Sub-surface drip irrigation is a low-pressure, low volume irrigation system that uses buried tubes to apply water. The impact of the water saving irrigation practices (DI, partial rootzone drying - PRD) will be assessed comparing performances with those of 100%-ETp irrigated plants in terms of WUE, but also monitoring physiological and biochemical stress parameters, and fruit quality indicators (Centritto *et al*., 2005; Tahi *et al*., 2007). DI and PRD are applied under critical growth stages for the improvement of WUE and qualitative-quantitative aspects of fruit production (Tahi *et al*., 2007; Aganchich *et al*, 2009). DI and PRD are sustainable approaches to cope with water scarcity since the managed water deficits favour water saving, control of percolation and runoff return flows and the reduction of losses of fertilizers and agrochemicals; it provides for leaching requirements to cope with salinity and the optimization approach leads to economical viability. The adoption of water saving irrigation practices implies appropriate knowledge of crop ET, of crop response to water deficits including the identification of critical crop growth stages and of the economic impact of yield reduction strategies.

Supplemental irrigation is used in arid zones by applying small amounts of irrigation water to crops that are normally grown under rainfed conditions. Advances in irrigation techniques and scheduling may further optimise water use efficiency (while preserving and even improving yield characteristics). Irrigation techniques and their scheduling have conventionally aimed to achieve an optimum water supply for productivity, with soil water content being maintained close to field capacity. This is commonly based on soil moisture measurements or water balance modelling. Localized irrigation is widely recognized as one of the most efficient methods of watering crops. Localized irrigation systems (drip irrigation, micro-sprayers) apply the water to individual plants by means of plastic pipes, usually laid on

the ground surface. With drip irrigation water is slowly applied through small emitter openings from plastic pipes with discharge rate ≤ 12 l/h. With micro-sprayer (micro-sprinkler) irrigation water is sprayed over the part of the soil surface occupied by the plant with a discharge rate of 12 to 200 l/h. The aims of localized irrigation are mainly the application of water directly into the root system under conditions of high availability, the avoidance of water losses during or after water application and the reduction of the water application cost (less labor).

Water Harvesting (WH) systems provide unique opportunities for strengthening water security through scientific rain water harvesting and watershed management. New systems to harvest water are applied to use runoff as the source of additional water. New fully mechanized systems have been adapted to different soil types and have been able to rehabilitate large areas of arid and semi-arid lands. However, because the fully mechanized system does not require the involvement of rural communities, in many areas the results were not sustainable and with time the microcatchment basins were abandoned. To overcome this problem, other systems to harvest water requiring the active participation of the rural community to produce mini-trenches microcatchments (trench, mini-trenches) were adopted. In the trench systems runoff was collected in deep trenches shaded by trees, to grow crops (fruit trees for dry areas, e.g. olive, deciduous fruit, etc.). Harvesting runoff water between two adjacent lines of trenches and storing it in the lower lying trench is a novel concept. Due to the geometrical properties of the trench and the fact that the canopy of the trees covers the trenches, the loss of water during and immediately after a runoff event is minimized and the thus "saved" water was available to the crops. The mini-trench system is a semi-mechanized WH technique and requires the active involvement of the rural community: empowering the local communities, through intensive capacity building programs, is an essential pre-requisite for the sustainability of this WH technique. The term "water harvesting" in this context includes all aspects of the systematic collection of runoff generated in the field and stored in the soil profile for agricultural purposes. Usually the collected runoff water is conveyed to microcatchments, i.e. ponded water in dam-surrounded plots, in which the crops/trees are planted. The vegetation within these plots has significantly higher water availability than the same type of vegetation growing outside these basins.

Drought stress is a complex syndrome, involving several climatic and edaphic factors, and is characterized by three major varying parameters: timing of occurrence, duration and intensity. The general complexity of drought problems is often aggravated under arid conditions, by erratic and unpredictable rainfall, the occurrence of high temperature, high levels of solar radiation, low soil fertility and increasing salinization. The resulting large variability in the nature and occurrence of drought stress and the insufficient understanding of its complexity have made it generally difficult to characterize the traits required to improve plant performance under drought, consequently limiting the use of a trait-based approach to enhance plant drought tolerance. It is well accepted that the complexity of the drought syndrome can only be tackled with a holistic approach, integrating physiological dissection of the resistance traits and molecular tools that identify the genes, proteins and metabolites involved in plant resistance mechanisms, together with high-throughput and precision practices (Loreto & Centritto, 2008; Centritto *et al*., 2009; Flexas *et al*., 2013). This will lead to better conservation and utilization of soil moisture, and to a better matching of plant species/genotypes/landraces with the environment, including the soil microbioma. This basic knowledge is essential to characterise plant resistance traits, and consequently to develop effective actions for combating aridity and desertification processes, and mitigating the impact of global change.

The key issue in combating land degradation in arid area is to select "climate proof" plants (crops and trees) with high agro-ecological potentials, to be integrated in either farming systems or ecosystem management, that make improved use of areas affected by erratic rainfall, drought and other associated stresses. The area of investigation on "climate proof" plants is still rather novel because there is very little information on the ecophysiological and molecular variability in water use of plants growing in arid environments. It is necessary to valorize the germplasm/landraces (grown in areas where they have advantages of adaptation to harsh conditions and as a consequence are able to withstand heat, salt, and drought) adapted to aridity through a combination of high-throughput phenotyping for drought resistance and improved water use efficiency, genetic and molecular approaches. Similarly, it is important to develop an accelerated route for producing new germplasm with enhanced drought tolerance whilst maintaining biomass productivity and quality in water scarce environments and in marginal dry environments unsuitable for food crops. Molecular research and genetic enhancement of value-added traits will improve efficiency of selection for resistance to drought and other abiotic stresses.

Quantitative assessment of plant growth and optimization of irrigation require the retrieval of real time data relating to crop condition and sensitivity to water stress. As a consequence, it is of paramount importance to improve non-invasive methods to monitor physiological traits, plant growth as well as plant and soil water status. The use of fresh water at farm scale can be significantly reduced through developing cost-effective management of irrigation equipment detecting real time crop physiological status, soil-water availability, and local climatic conditions. To this end, a very broad and interdisciplinary approach is used for the development of technological tools and automated systems. This implies application of high-performance technologies: real-time, non-invasive sensors to detect soil and plant water status, agro-meteorological technologies, last generation information and communication technology control

systems, remote sensing and geographical information systems technologies (Marino*et al*., 2014; Sun *et al*., 2014). Furthermore, major progress has been made with the use remotely sensed vegetation indices to assess physiological traits associated with plant water status.

Conclusion

The fight against aridity and desertification must be addressed with an approach based on the restoration of ecosystem services aimed at improving the resilience of arid areas. This requires interventions aimed at increasing the complexity of biodiversity, in terms of both species richness and functional diversity, upon which ecosystem function depends and thier services. Water shortage interacts with a shortage of food, consequently there is real potential for driving significant international problems. Reducing the use of agricultural water is an aim that requires combined agronomic, physiological, biotechnological/genetic and engineering approaches, which may be collectively described as 'water saving agriculture'. This requires a systematic identification of interconnections between the functioning and resilience of arid ecosystems, the ecosystem services they provide and the teleconnections in the climate system within a framework of biophysical and socio-economic changes. The knowledge of the extent of these processes and changes of arid ecosystems over both short and long terms, are of the utmost importance to improving the effectiveness of programs of rehabilitation of degraded ecosystems, rational development strategies and adaptation / mitigation of the impacts of climate change. Furthermore, the adoption of improved agricultural technologies in different hydrological, biological and socio-economic conditions is essential to ensure integration of those technologies within diverse regional contexts and to support the livelihoods of small farmers.

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New challenges in olive orchard management

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Abstract

Olive was introduced into cultivation more than 3000 years ago. The old traditional olive production systems around the Mediterranean the main production area is dry-farmed. The tree spacing, depending on the rain average range from 24 meters apart (17 trees per hectare) to a spacing of about 8 meters apart (155 trees per hectare). Many of the old orchards are also conducted with minimum technical cares, mainly pruning and sometimes only every two years and without any mineral nutrition. And each traditional production area is using its own cultivars.During the last two decades, the olive cultivation is shifting from this traditional situation to a more completely mechanized orchard with a super high density (SHD) conducted in hedgerow with drip fertigation, mechanized pruning (topping and hedging) and harvest. This change is occurring in new olive production areas, but also around Mediterranean in the traditional zones. Only three cultivars (‘Arbequina’, ‘Arbosana, ‘Koroneiki’) dominate the SHD orchards. This development responds to the need for mechanization to reduce production costs, respond to the lack of workers and reduce the time to enter into production.However, better knowledge and studies are needed to understand this new challenge for the olive orchard management.

Key words: Olive; orchards; challenges; management practices; mechanization

Introduction

The olive tree is one of the oldest and the most important crops of the Mediterranean Basin. For thousands of years, olive tree was conducted in an extensive production system. This system is characterized by the absence of water supply (rainfed), the low density of plantation, the use of vigorous local varieties and based on family labor. Tree spacing ranges from 24 meters apart (17 trees per hectare) to 8 meters apart (155 trees per hectare). Minimum technical cares were provided to the tree, mainly pruning and sometimes it is done only every two years and without any mineral nutrition. However, from the second half of 20th century, the important socioeconomics changes and the advances in agricultural sciences and technology, growing demand for olive oil and plantation in new regions and areas have led to important changes in olive production systems (Fernandez-Escobar *et al*., 2013). In fact, different systems of intensification of olive tree have been developed: intensive, semi-intensive and super-intensive.

Among the different intensification systems, the super-intensive or super high density (SHD) production system is the latest and the most widespread. The most important objectives of this system are to reduce unproductive period, increase production per unit area and reduce costs by mechanizing all operations (pruning, harvesting, etc). However, this system of production is facing a numerous challenges in relation with the genetic resources and on the cultural practices, which can compromise its future. In the last years, important efforts have been deployed to enhance the management and to determine the best practices for this system (Rallo *et al*., 2013).The main aim of this paper is to give an overview on the progress made on the management of the SHD orchards and the challenges remain to be solved.

Genetic resources

The SHD orchards are dominated by a few and traditional cultivars: ‘Arbequina’, ‘Arbosana’, and ‘Koroneiki’. ‘Arbequina’ is the most used cultivar in SHD, but ‘Arbosana’ seems to be more appreciated by growers, due to its tolerance to the “Peacock Spot” disease and to its reduced vigor (De la Rosa *et al*., 2007; Sai *et al*., 2012). ‘Koreniki’ is considered in several olive growing regions as less suitable for SHD in comparison with ‘Arbequina’ and ‘Arbosana’ (De la Rosa *et al*., 2007; Godini *et al*., 2011; Sai *et al*., 2012).

After two decades of experience with SHD production system, some limitations related to the excessive vegetative growth of the traditional olive tree cultivars, indicate the necessity of developing new varieties with low vigor. In fact, the use of this type of varieties will extend the productive period in SHD orchards. In the last fifteen years, classical olive breeding programs were developed in several olive-producing countries. However, few new varieties were obtained by these programs, principally due to the very long juvenile period for the olive seedlings (more than 15 years) (Fernandez-Escobar *et al*., 2013). In addition, most of the obtained varieties have shown modest results in comparison with traditional cultivars in the SHD production system (Lavee *et al*., 1986; De la Rosa *et al*., 2007; Rallo *et al*., 2008).

Since the beginning of this century, simple and efficient methods based on cultural techniques and early selection criteria were established for reducing juvenile period in olive seedlings. In addition, an important advance was made in developing early selection criteria for low vigor and adapted growth habit to the cultural practices in SHD orchards (training, pruning and the mechanical harvesting) (Hammami *et al*., 2012). All this progress can increase the efficiency of the olive tree programs and shorten the selection procedure.

Density of plantation

Increasing the olive tree density leads to greater interception of radiation, in particular during the period of orchard development when trees cover only a small fraction of the ground. As the trees grow, their canopies occupy more space, and mutual shading occurs (Pastor *et al*., 2007). However, to maximize orchard production, it was necessary not only to intercept the maximum amount of radiation possible, but also to optimize the distribution of radiation within the canopy for maximum production efficiency (Jackson, 1980; Pastor *et al*., 2007). The choice of the adequate density of plantation and of the row orientation for each variety and environmental conditions will allow the growers to achieve this objective and also to maximize the productive life of their orchards. In fact, the vigor and the growth habit are the most important variety characteristics, which affect seriously the interception of radiation and the duration of the period without mutual shading between the canopies. Environmental factors, such as soil, temperatures and sunshine duration, have an important effect on the intensity of vegetative growth and can modify the growth habit of the tree (Meinzer *et al*., 2011).

At the beginning, little attention was paid for the choice of the density of plantation in SHD olive orchards. The number of tree per hectare, varied greatly for different varieties and regions of olive growing, from 1000 to 2000 (Fernandez-Escobar *et al*., 2013). In last year, several studies were performed in order to determine the effect of the density of plantation on yield for different cultivars. ‘Arbequina’ and ‘Arbosana’ (Spanish cultivars) seem to be the most suitability cultivars for the SHD production system (De la Rosa *et al*., 2007; Godini *et al*., 2011; Larbi *et al*., 2011a). That is mainly attributed to their lowest vigor, highest yield and adaptation to different environmental conditions, in comparison with other traditional cultivars. However, ‘Arbosana’ is most recommended for the highest density due its lowest vigor in comparison with ‘Arbequina’ (De la Rosa *et al*., 2007; Larbi *et al*., 2011a; Sai *et al*., 2012).Recent studies on olive SHD orchards have shown the importance of orientation, row height, row width and canopy slope to identify combinations that maximize incident solar radiation interception and, thus, productivity (Connor, 2006). The north-south orientation of row ensures the highest interception of the radiation in the SHD olive orchards.

Pruning and vigor control

For fruit species, we found three main types of pruning: for training, for fruiting and for rejuvenation (mainly for traditional olive orchards). The application of these types of pruning depends on the tree age, and has different objectives.

The pruning for training aims to modify the natural shape of the tree during the first years of the plantation, in order to obtain the most adapted form for the further cultural practices (spraying, tillage, harvest etc.) and to maximize the use of the solar radiation. Forming the tree in central axis is considered the most adequate for the SHD plantations. That consists in fostering the development of one central axe, by removing the other vigorous branches during the first 2 years, until it is became the dominant. However, that is not always easy for olive tree. In fact, the majority of olive cultivars have a strong trend to “basitony”, which make it difficult to train for central axe (Gucci and Cantini, 2000). Recent studies have indicated the possibility of selecting new varieties easy to form in central axe (Hammami *et al*., 2012).

The realization of a classical pruning for fruiting in the SHD olive orchards is very expensive. In addition, a manual pruning may be inefficient due to lack of sufficient knowledge on the process of pruning of olive tree conducted in hedgerow. The mechanical pruning seems to be a suitable alternative, which can reduces costs, ensure the renewing of the production structure and adapt the tree shape for the other mechanical operations (harvesting) (Sibbett and Ferguson, 2005). There are two types of mechanical pruning: the “topping” (reducing tree height) and the “hedging” (eliminate part of lateral growth of one or two faces of the row) performed by means of an articulated disks pruner coupled at the front of a tractor. In spite of the encouraging obtained results, these practices are relatively recent in SHD olive orchards and few reports were available about the long term effects of the mechanical pruning on the yield-components. Further investigations are required to understand the right width of hedging and the height of “topping” to reach the correct equilibrium between vegetative and reproductive activity in adult orchards, with an architectural approach (Vivaldi *et al*., 2015). Especially that topping and hedging are the key cultural practices for having fruit set on all part of the tree and to harvest mechanically. The actual tendency for SHD pruning is to make the hedging every three

years on the same side of the tree. So we have one year it is cut at 1.2 to 1.5 m on one side of the tree. The year after, it changes to the other side of the tree. And the third year no hedging is done.

Other technical practices were proposed to control the vegetative growth in the SHD olive orchards. Fernandez *et al*. (2013) have proposed a deficit irrigation strategy to reduce vigor in SHD olive orchards, with the minimum reduction of oil yield and the maximum water saving. In other studies, the use of the Plant Growth Regulators (PGR) has been tested to modify growth habit and to reduce vigor in hedgerow orchards. In SHD orchards planted by different cultivars, a soil application of 0.1g of uniconazol/tree (a gibberellins synthesis inhibitor) reduces significantly olive tree vigor and increase olive production (Avidan *et al*., 2011).

Irrigation management

The high density of plantation in SHD, increase considerably the potential transpiration, which make the irrigation imperative. That is especially true in the most olive growing regions, where the rainfall does not exceed the 500mm/year. Up to now, the water requirements of SHD orchards was estimated using models of water demand in response to orchard density and canopy volume, and fully provided by drip irrigation (Orgaz and Fereres 2008; Fernandez-Escobar *et al*., 2013; Rallo *et al*., 2013). However, in the last years the excessive tree vigor observed (important vegetative growth) in SHD olive orchards have attributed in part to the full irrigation. In addition, in the most olive producing-countries the water resources are scarce. Consequently, the development of a deficit irrigation strategy in SHD orchards has become very important to increase their sustainability and productivity.

Recent studies have been proposed different deficit irrigation strategies to control vigor and to save 20 to 70% of water of irrigation, with the minimum reduction in yield (Fernandez *et al*., 2013; Gomez-del-Campo, 2013; Padilla-Diaz *et al*., 2015). These strategies of regulated deficit irrigation consists on supply the totality of water requirements during the phases of the growing cycle when the crop is more sensitive to water stress, and reducing or even withholding irrigation for the rest of the cycle (Fernandez *et al*., 2013). Thus, is important for olive tree to avoid water deficits during the bloom, beginning of pit hardening and from 2 to 3 weeks before ripening, which considered the most sensitive for water stress (Moriana *et al*., 2003; Tognetti *et al*., 2005).

Nutrient management

Mineral nutrition management is necessary for the SHD system. During the three first years, the objective is to maximize early vegetative growth using mainly nitrogen. When the orchard starts to produce, it is needed to replace the nutrient losses due to yield, pruning and leaching by adequate mineral nutrition (Connor *et al*. 2014). The fertilization is typically done by fertigation and concern mainly three minerals nitrogen, phosphorus and potassium using small doses over most of the growing season. To control the nutrition program, the leaf tissue analysis is highly recommended and must be an annual routine procedure (Freeman *et al*., 2005; Fernández-Escobar *et al*., 1999; Rodrigues *et al*. 2012). Nitrogen is important for the vegetative growth but a high level of this nutrient may cause excessive growth and reduce oil quality (Connor *et al*. 2014, Fernández-Escobar *et al*., 2006). Potassium is the main mineral element for olive fruit growth and during oil synthesis. A potassium foliar spray is used during these periods. A micronutrient which is also important especially for fruit set in SHD is Boron that is recommended to consider just before flowering and after fruit set (Larbi *et al* 2011b).

Mechanical harvesting

The full mechanization of olive fruits harvest, in order to reduce the high costs of manual harvest and make face for the increasing scarcity of the workforces in agriculture, is one of the most important justification of the implementation of the SHD olive orchards. Different methods and machineries have been proposed to harvest olives (Sibbett and Ferguson, 2005; Fernandez-Escobar *et al*., 2013).

The continuous harvesting system is considered the most suitable and efficient system for the SHD olive orchards (Rallo *et al*., 2013). The straddle harvesters used in this system allows to remove, clean and load fruits into bins uninterruptedly. This system ensures a high efficiency of fruit removal (more than 90% of the fruits/tree) in comparison with the trunk shaker machine. However, is necessary to maintain a small size of the tree canopy (height <4m and width <1.5m), by mechanical pruning (topping and hedging) (Fernandez-Escobar *et al*., 2013). Additionally, the high price of this machine limits its acquisition to the large farms. For the small farms is possible to pay the service of harvesting for specialized companies or for the large farms which have the harvester machine.

Conclusion

During the last decades the olive world is changing with new area and region planted with olive and new cultural practices adopted by the grower. The SHD system is one of the results of this changing process induced by the lack of workers and the necessity to mechanize almost all the cultural practices. However, the superhigh-density system is not simple. It requires a more important investment capital, more water and fertilizer and great deal of skill. It needs to plant the adequate cultivar in the right site and climate and to have an excellent technical knowledge of olive good agricultural practices adequate for the SHD. All these constraints must be taken into consideration since the quality of the olive oil and the success of the orchard depend on them.

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Sustainable irrigation scheduling and water quality for olives

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Abstract

Olive trees can grow without irrigation in areas with annual rainfall of 400-600 mm, but for high yields irrigation during the dry months is essential. The critical growth stages for water for olive are: 1) the bud differentiation 2) the flowering and fruit-set and 3) the pit hardening and rapid fruit development. Water deficits may result in reduced number of inflorescences, production of imperfect flowers, flower drop and reduction of the fruit set percentage. Furthermore, it reduces the annual shoot length, leaf area, leaf number and next years' yield. Adequate soil water increase the number of fruits (mostly to trees with small or medium production) and the total oil production per plant, while fruit oil content is reduced from 0 to 10%. Irrigation may reduce polyphenol content and increase saturated fatty acids, while K232, K220 values and organoleptic olive oil characteristics are not affected. The irrigation requirements of olive tree vary according to the cultivar and the growth stage. Olive tree is considered as moderately salt tolerant and recent studies suggest that olives can be irrigated with water containing 3200 mg/l of salt (ECw of 5 dS/m) producing new growth at leaf Na levels of 0.4-0.5% d.w. Salt tolerance in olives appears to be cultivar-dependent and is likely due to control of net salt import to the shoot. High salinity generally reduces olive yield. Salinity increases or does not affect oil content of the fruit, although the extent of this reduction changes with cultivar. Furthermore, NaCl salinity induces changes in fatty acid composition an increases the total phenol content of olive oil.

Key words: Olive; irrigation; water requirements; water quality; yield

Introduction

The olive is xerophytic plant and can grow without irrigation in regions with rainfall 400-700 mm or even 200 mm. For high production and good growth it requires 600-800 mm rainfall per year. Since the distribution of rainfall throughout the year is not uniform and in many areas there are extended drought periods during summer with intense evaporation and transpiration rates from the plant, irrigation is necessary.The critical periods for water of olive are a) the period of bud differentiation and flower formation (January-February), b) the period of flowering and fruit set (in April-May) and c) the period of pit hardening and rapid increase of fruit (August-September). For the 1st period in Mediterranean countries the water needs are covered by the rains of winter and spring. When the rains of winter are limited the irrigation is necessary before the beginning of blossoming (April May), in order to is ensured sufficient soil moisture at flowering and fruit set. The third period (pit hardening and rapid fruit growth) the water requirements are necessarily covered by irrigation.

Effects of irrigation on olive

The critical growth stages for water for olive in northern hemisphere are the bud differentiation (January-February), the flowering and fruit-set (mid April-May) and the pit hardening and rapid fruit development (August-September). In Mediterranean Basin the adequate soil moisture during bud differentiation is provided by the winter rainfall, while for the other critical stages of olive, for water irrigation in most cases is necessary. The effects of irrigation in the growth and production of olive are reported in the Table 1.

Table 1: Effects of irrigation on olive tree growth and production

Root system	Reduce the length of root system, reduce the percentage of assimilates towards the roots, more shallow root system.
Shoot growth	Increase the length of annual shoo growth, increase the leaf area and the leaf number, increase the yield of next year.
Flowering fruit set	Increase the production of perfect flowers and the % of fruit set, in some cultivars reduce alternate bearing. Water stress cause fruit drop and reduce the % of fruit set.
Fruit production	Increase the size of the fruit (mainly in trees with low or medium load), increase the number of fruits per tree, increase the total oil production per tree and may reduce fruit oil content (0-10%).
Olive oil quality	Reduce polyphenol content, increase saturated fatty acids while K_{232}, K_{270} are not affected. Rational irrigation do not affect negatively the organoleptic characteristics of olive oil and are classified as extra virgin olive oils.

The olive tree presents two phases of growth of new vegetation, intense in spring up to the beginning of summertime, when floral induction takes place, and a less dynamic phase in the fall. The sufficient soil moisture at these phases influences favorably the growth and the production of olive. Under rain-fed conditions, root length densities (RLD) are low, e.g. 0.177 cm/cm3 to a depth of 1.5m for roots <0.5mm diameter in an area of 4 by 4 m, centered on trees spaced at 7 by 7m (Fernandez *et al*. 1991). Irrigation increase the total annual shoot length (active growth stage), leaf area and leaf number (Xiloyiannis *et al*., 2002). Insufficient soil moisture in spring (March April) causes production of big number of incomplete flowers and decrease the annual growth resulting in reduction of production of current and probably next year.

Sufficient soil moisture during annual growth stages (March-June and September-October) tends to decrease alternate bearing in some cultivars. Adequate water supply during flowering increase the number of perfect flowers, while during fruit set increase the percentage of fruit set. Water stress reduces the number of inflorescences, increase the production of imperfect flowers, increase flower drop percentage and reduce fruit set percentage. During this period reasonable amounts of irrigation water should be applied. Under certain conditions (excessive water, sandy soils) irrigation during flowering period may lead to soil nitrogen leaching and fruit drop.

Under Mediterranean conditions fruit yield is responsive to water supply and it is of interest to place the yield of rain-fed olive in the perspective of yield achievable when fully supplied with water (Moriana *et al.*, 2003). The response depicted in Fig. 1 summarizes irrigation treatments applied for 4 years to a 30-year-old orchard of cv 'Koroneikil' at Messara, Crete, Greece (Chartzoulakis *et al.*, 1992). Olive yield display a-curvilinear relationship to orchard evapotranspiration (ETc) with a 2-fold increase over the range 500–950 mm. The irrigation increases the production mainly by increasing the number of fruits per plant and less the size of fruits. In most cases also increase the oil content of the fruit and finally increase the total oil production per tree. On the other hand irrigation delays maturation (gradual color change and high oil content is reached later). Satisfactory irrigation increases the production (final) olive oil per tree until 70 % (M.O. 30-58%) depending on soil type and the situation of plant. The irrigation should stop in October in order to have a period for the maturation of the fruits.

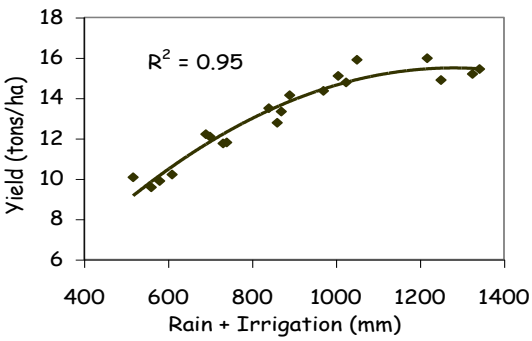

Figure 1. Relationship of yield (t/ha) to evapotranspiration for cv 'Koroneiki' (Chartzoulakis *et al.*, 1992)

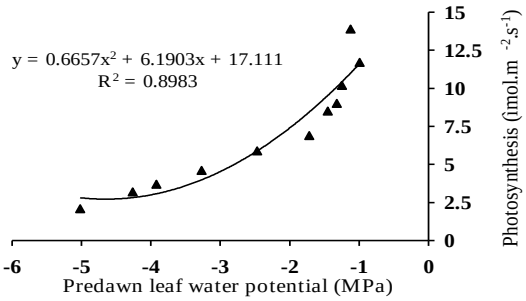

Figure 2. Relationship between maximum Pn and predawn leaf water potential during the drought cycle (Chartzoulakis *et al.*, 2000)

Olive oil quality is also affected by irrigation. Phenolic compounds of olive oil appear to be the most influenced by irrigation, with the effect varying with the amount and time of water applied to the trees (including the type of irrigation management), the climatic conditions, and the variety (Patumi *et al.*, 2002; Rico *et al*., 2006; Stefanoudaki *et al.*, 2009). Moreover, water stress influences the organoleptic properties of olive oil and its oxidative stability. The antioxidant activity of phenolic compounds is well-known, as is the correlation of some phenolic compounds with sensory attributes of olive oil, especially bitterness and pungency. More recent research findings (Servilli *et al*., 2007; Grab *et al.*, 2014) have reported that the volatile profile of olive oil is also influenced by irrigation of olive trees.

Defense mechanisms to drought

The olive can withstand long period of drought. The tree is able to slow the onset of stress by control of transpiration and by water uptake from a widely exploring root system. The ultimate drought strategy, however, is

tolerance, the ability to sustain large internal water deficit and maintain sufficient metabolic activity for survival. There is, therefore, a wide range of morphological and physiological responses that can contribute to maintaining internal plant water status within physiologically acceptable limits by adjusting demand and/or uptake in response to environment and soil water content. Leaves formed under water stress are more able to control transpiration, being smaller and thicker and having more dense and smaller stomata (Chartzoulakis *et al.*, 1999; Bosabalidis and Kofidis, 2002).

The mechanisms that contribute in the drought resistance are a) the osmotic adjustment, i.e. the drastic reduction of osmotic potential (Ψp) in the cells that are under water stress (Chartzoulakis *et al.*, 1999; Dichio *et al.*, 2003) that is owed to the loss of water from the cell and the increase of production of osmotic active substances. More than 65% the change of Ψp is owed to the active production and stocking of osmotic active substances (Xiloyiannis *et al*., 1999; Chartzoulakis *et al*., 2000), mainly mannitol and glucose. b) The elasticity of cell wall (ε) of olive, which increases under water stress conditions (Chartzoulakis *et al*., 2000; Dichio *et al*., 2003). The olive under such conditions mobilizes metabolic activities for production of substances that increases the stability of cell walls.

Photosynthesis of water-stressed olive trees decreases gradually under -1,3 MPa predawn Ψl (Xiloyiannis *et al*., 1999; Chartzoulakis *et al*., 2000). The reduction of photosynthesis is closely connected and with the closure of stomata (Giorio *et al*., 1999). Under severe water stress (-5 MPa predawn Ψ) olive tree still photosynthesize (Fig. 2), allowing the olive to continue producing assimilates and distributing them the various parts of the plant, mainly in the root, creating a higher root/shoot ratio.

The olive has high recovery capacity, following the irrigation, to normal values (Moriana *et al*., 2002). Water relations parameters recover almost fully overnight after re-watering the plants, while photosynthesis and stomatal conductance show a 80% recovery (Chartzoulakis *et al*., 2000) The rapid recovery of water relations parameters (Ψ, Ψπ and RWC) may be associated with the non full recovery of leaf funcionability and the capacity of olive roots to absorb water (Dichio *et al*., 1997). Angelopoulos *et al*. (1996) reported that the delay in full recovery of photosynthesis after-watering is associated with the non immediate recovery of non-stomatal factors of photosynthesis, particularly of those linked with the functionality of the primary photochemistry associated with photosystem II.

Water application and irrigation scheduling

Irrigation system to be used depends on the amount of the available water, the soil characteristics and the climatic conditions.The irrigation water can be applied using various traditional surface methods, like basins and furrows. However these methods require large water supplies, which usually are not available, high labor cost and have high losses of water during application. In case that these methods are applied, 1-2 irrigations per month during June-July-August-September can meet the water requirements of olive.

Localized irrigation is usually the most appropriate irrigation method for olives since it ensures high soil water availability, efficient water use (efficiency up to 95 %), reduced labour cost (can be automated), easy and efficient fertilizer application, reduced salinity hazards, can be used on uneven or sloping areas and utilize small water discharges.

The irrigation scheduling can be based on soil or plant measurements and climatic parameters. The use of physiological parameters (water potential, stomata resistance, etc) requires special devices, usually very expensive and specialized knowledge. The irrigation scheduling based on soil moisture sensors (tensiometers, TDR, etc) is effective only in olive groves with homogeneous soils. Is mainly recommended the irrigation scheduling to be based on the climatic data, especially on class A pan evaporation data, which are usually available in most government owned services. The application of 4 irrigations per each month during June-July-August-September is advisable.

The water requirements of olive depend on the use of the variety (oil extraction or table olives) and the growth stage (Table. 2). The table varieties require bigger quantities of water than those used for oil production. The irrigation increased the production of cv Koroneiki by 33-58% and the water requirements are estimated to 2000-2500 m^3/ha under Cretan conditions with a A Pan crop coefficient Kp = 0.3 (Chartzoulakis *et al*., 1992). The oil content of the fruit (% dw) in irrigated olives is lower or not affected in most cultivars than in rain-fed. For the Greek table cultivars `Kalamata' and `Amfissis' under drip irrigation an A Pan crop coefficient Kp= 0.40–0.45 (3000-3500 m3/ha is considered satisfactorily to cover their needs in water (Michelakis, 1990).

Table 2: Irrigation water requirements of olives (liter/tree per day) under Cretan conditions

Use of the fruit	Μήνες					
	MAY	JUNE	JULY	AUGUST	SEP	OCT
Oil production	30 - 40	40 – 50	50 - 60	50 - 60	40 - 60	-
Table olives	40 - 50	70 – 80	80 - 100	80 - 100	60 - 70	50 - 60

Salinity and olive

Olive is considered a moderately salt tolerant plant (Mass and Hoffman, 1977; Rugini and Fedeli, 1990), although salinity may be a problem in Mediterranean area due to high salt concentration in irrigation water. In comparison to other Mediterranean tree crops, the olive tree is more tolerant than citrus but less tolerant than the palm tree. The type of salts contained in the irrigation water is also related to the degree of plant damage. Bartolini *et al*., (1991), irrigating one-year old olive plants, cv Maurino, containing either NaCl or Na_2SO_4, reported that Na_2SO_4 was more deleterious to general growth than NaCl. Guidelines for quality of irrigation water for olive-trees are given in Table 3.

Table 3: Irrigation water quality guidelines for olives

Irrigation problem	Degree of problem		
	None	Increasing	Severe
Salinity			
EC_w (dS/m)	<2.5	3-5	>5.5
Specific ion toxicity			
Sodium (g/l)	0.25	0.3-1.0	>1.2
Chloride (g/l)	0.35	0.4-1.5	>1.8
Boron (ppm)	1-2		

The reuse of reclaimed wastewater is a potential and cost effective source for irrigation water in olive-growing areas, especially under fresh water scarcity conditions. The utilization of RWW to irrigate olive orchards have been practiced in many Mediterranean olive growing countries (Palese *et al*., 2006; Segal *et al*., 2008; Bedbabis *et al*., 2010). Since the olive oil is consumed after olive fruit processing, the risk from direct exposure to pathogenic microorganisms present in RWW is decreased (Palese *et al*., 2009).

Tolerance to salt appears to be cultivar-dependent. Genotypic responses of olive to NaCl salinity have been only recently investigated and some works have been published (Benlloch *et al*., 1994; Tattini *et al*., 1994; 1996; Chartzoulakis *et al*., 2002; Chartzoulakis, 2005). The growth of all cultivars tested so far is reduced under salt stress to varying degrees. A list of olive cultivars tested for salinity tolerance is given in Table 4. It is likely that the tolerance of adult plants grown under field conditions will be different than that obtained with young plants grown in pots.

Mechanisms of salt tolerance in olives are likely due to control of net salt import to the shoot. The mechanism is located within the roots and prevents salt translocation, rather than salt absorption and retention of sodium and chloride in the roots (Tattini *et al*., 1994; Chartzoulakis *et al*., 2002). The effectiveness of exclusion mechanism depends on the salinity level. At low and moderate salinity most olive cultivars exhibit a sodium exclusion capacity. This mechanism seems to work effectively at levels of salinity up to 50 mM NaCl, but it slows down plant growth. At high salinities in salt sensitive cultivars, Na+ was transported and accumulated to the aerial parts, resulting in toxicity symptoms. Typical NaCl toxicity symptoms in olives are dead leaf edges, leaf drop and necrosis of stem tip. Toxicity symptoms appear at exposure above 50 mM in salt-sensitive cultivars and become more severe at high salinity levels (Chartzoulakis, 2005, 2011).

Effects of salinity on olive growth and production

Plant growth, (i.e. shoot length, trunk circumference, total leaf area, dry weight, root length) is inhibited by moderate and high salinity (Therios and Misopolinos, 1988; Marin *et al*., 1997; Chartzoulakis *et al*., 2002, Ben-Ahmed *et al*., 2008; Perica *et al*., 2008). The extent of reduction varies significantly according to the duration of salt exposure and the cultivar. Leaf area is more sensitive than total dry weight.

Dry matter partitioning is also affected, since the above ground part of the plant is more affected than are roots at high salinity. The shoot/root ratio is reduced at salinity levels of 100 and 200 mM (Therios and Misopolinos, 1988; Chartzoulakis *et al*., 2002). However, Tattini *et al*. (1995) reported that the inhibitory effects of salinization on growth and gas exchange of the salt-tolerant 'Frantoio', grown even at 100 mM NaCl, fully recovered, reaching values similar to the control, once salinization was relieved despite the marked accumulation of potentially toxic ions (Na, Cl) in leaves. At high salinity levels (200 mM NaCl) plants recovered to only 60% of the control after 4 weeks of relief.

Studies on the effect of salinity on yield of olive trees are few and their results inconsistent. It is generally accepted that high salinity levels reduce olive tree yield (Gucci and Tattini, 1997; Chartzoulakis, 2005; Ben-Ahmed *et al*., 2009). In most reported long-term field studies, negative effects of salinity on yields were found only when exposure to salts became extreme. Klein *et al* (1992) reported either an increase of 12% (high density planting) or a decrease of 18% (low density planting) in the yield of Manzanillo trees, irrigated with 4.2 dS/m under field conditions. Weisman *et al*. (2004) reported that young Barnea olive trees irrigated with 4.2 dS/m water produced 20% higher yield than those irrigated with 7.5 dS/m. In another field study on 12 cultivars Weissbein *et al*. (2008) reported no significant effect of salinity on oil yield between irrigation with EC 1.2 and EC 4.2 dS/m as long as upper soil layers (to a depth of 60 cm) were leached so as to maintain less than 6.0 dS/m ECe. Melgar *et al*. (2009) reported no yield reduction in cv 'Picual' irrigated with 10 dS/m for 9 years while Ben-Ahmed *et al*. (2009) reported that 'Chemlali' olives irrigated with high saline (7.5 dS/m) for two years had 35% lower fruit yield compared with good quality (1.2 dS/m) water.

Table 4: Classification of olive cultivars according to their salt tolerance

Resistance	Cultivar	Country	Source
Tolerant	Megaritiki, Lianolia Kerkiras, Kalamata, Kothreiki	Greece	Therios & Misopolinos 1988; Chartzoulakis *et al*., 2002
	Frantoio	Italy	Tattini *et al*., 1992; Tattini *et al*., 1994
	Arbequiña, Picual, Jabaluna Nevadillo, Lechin de Sevilla, Cañivano, Esscarabajuelo,	Spain	Benlloch *et al*., 1994; Marin *et al*., 1995 ; Melgar *et al*., 2009
	Hamed	Egypt	El-Sayed Emtithal *et al*., 1996
	Chemlali	Tunisia	Bouaziz 1990
	Barnea	Israel	Weisman *et al*, 2004
Moderately tolerant	Amphissis, Koroneiki, Mastoidis, Valanolia, Adramitini	Greece	Therios and Misopolinos 1988; Chartzoulakis *et al*., 2002
	Maurino, Coratina, Carolca, Maraiolo	Italy	Briccoli Bati *et al*., 1994; Tattini *et al*., 1994; Bartolini *et al*., 1991
	Aggezi, Mostazal, Toffahi, Wardan		El-Sayed Emtithal *et al*., 1996
	Nabali Muhassan	Jordan	Al-Absi *et al*., 2003
Sensitive	Chalkidikis, Throubolia, Aguromanaki	Greece	Therios & Misopolinos 1988; Chartzoulakis *et al*., 2002
	Leccino	Italy	Tattini *et al*., 1994
	Bouteillan, Nabal	Egypt	El-Sayed Emtithal *et al*., 1996
	Pajarero, Chetoui, Calego, Cobrancosa, Meski	Spain	Benlloch *et al*., 1994; Marin *et al*., 1995

High salinity does not affect or decreases fruit weight and increases the moisture content of fruits (Stefanoudaki *et al*., 2001; Weisman *et al*., 2004; Ben Ahmed *et al*., 2009; Klein *et al*., 1994). Salinity increases or does not affect oil content of the fruit (Klein *et al*., 1994; Weisman *et al*., 2004; Melgar *et al*, 2009), although the extent of this reduction changes with cultivar (Zarrouk, *et al*., 1996; Weisman *et al*., 2004).

There is little information regarding the effect of salinity on olive oil quality (Gucci and Tattini, 1997; Chartzoulakis, 2005, 2011). Short-term results showed that total phenol concentration increased in the olive oil produced with high NaCl levels of irrigation water (Weisman *et al*., 2004; Stefanoudaki *et al*., 2009a; Ben Ahmed *et al*., 2009), as has been also reported for water stress (Cresti *et al*., 1994). Increases due to salinity were found in major phenolic compounds including tyrosol, hydroxyltyrosol, and vanillic, coumaric, and ferulic acids. Fatty acid composition of olive oil is also affected by salinity (Zarrouk, *et al*., 1996). Palmitic acid, the major saturated fatty acid as well as the total saturated fatty acids increase with increasing salt concentration in the irrigation water (Stefanoudaki

et al., 2001). The ratio of unsaturated/saturated fatty acids was higher in the control and decreased significantly at moderate and high salinity levels (Zarrouk, *et al*., 1996; Weisman, 2004). In addition, the oleic/linoleic acid ratio decreased as the salinity of water used for olive irrigation increased (Cresti *et al*., 1994; Ben Ahmed *et al*, 2009). These changes may account for accelerated fruit ripening (Marzouk *et al*., 1990). No effect on free fatty acids, peroxide, or fatty acid profile was reported by Weisman *et al*. (2004) for 'Barnea' irrigated with saline (4.2 or 7.5 dS/m) water. Polyphenols and vitamin E increased as irrigation water salinity increased from 1.2 to 4.2 dS/m but did not change further as irrigation water EC increased to 7.5 dS/m.

Management practices under saline irrigation for olives

Management practices must prevent excessive salt accumulation and sodicity in the soil surface and root zone and control the salt balance in the soil-water system. Irrigation management practices for saline water for olive-trees include proper irrigation scheduling (amount of water and interval), efficient leaching (amount and timing), proper irrigation method, management of multi-quality waters, use of water or soil amendments and the use of arbuscular mycorrhizae.

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Use of micro catchment rain water harvesting combined with micro irrigation technique in olive for sustainable water management

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Abstract

Rainwater harvesting structures can be very useful for semi-arid and dry, sub-humid regions to enhance the water productivity. Among the available irrigation techniques, micro irrigation method is one of the irrigation techniques that can help farmers to produce crops with minimum water resources as compared to the conventional irrigation methods. Experiments were conducted at Barani Agricultural Research Institute (BARI) where the climate is semiarid subtropical and the annual rainfall varies from 500-1000 mm. The starting point of rainwater harvesting was to capture rain water where it falls, that is micro catchment rain water harvesting. Three field plots were used to evaluate the performance micro catchments rain water harvesting techniques on olive plant. Three different shapes; square, rectangular, and triangular or V shape were constructed with 3-5% slope for olive plants to harvest rainwater. It is concluded that micro catchment structures are best suitable to this terrene and only three supplement irrigations were required for olive plant through drip/bubbler irrigation system. Total water requirement of the olive tree is 650mm/year. Average effective rainfall of 2013 and 2014 was 594 mm from which 505 mm (85%) was used by olive plants in micro catchments. The remaining water (145 mm) was applied through supplemental irrigation using bubbler irrigation method, which again saved 60% water as compared to flood irrigation method. Yield increase of 8-9% was also recorded in micro catchment rainwater harvesting structures. Therefore by constructing micro catchment structure we can save the water of irrigation while drip and bubbler irrigation can be used as supplement irrigation technique in micro catchments.

Key words: Rainfed; rain water harvesting; micro irrigation; soil moisture

Introduction

Rainfed agriculture provides nearly 60%of global food value on 72% of harvested land whereas about 70% of the world's poor people live in these areas where livelihood options outside the agriculture are limited. Selection of better crops and management of soil, rainwater, soil moisture, and supplemental irrigation are the key factors to improve land and water productivity and livelihood of these areas (Albeyi *et al*. 2006; Passioura, 2006). Olive is a drought-tolerant tree which is usually grown in areas with a Mediterranean climate that receive more than 350 mm of annual rainfall. However, olive growing in Syria has now expanded into drier areas (200–300 mm annual rainfall) where irrigation resources are limited (Tubeileh *et al*., 2009). Rainwater harvesting structures can be very useful for semi-arid and dry, sub-humid regions especially as water scarcity is caused by extreme variability of rainfall rather than the amount of rainfall. Under such conditions, with high rainfall intensities, few rain events, and poor spatial and temporal distribution of rainfall, even if total rainfall is adequate, water losses are very high, thus leading scarcity (Rockstrom *et al*., 2009).

Water productivity can be enhanced by (i) improving the production per unit of water consumed, or (ii) by maintaining the same production while reducing water use (Kijne *et al*., 2003; Rijsberman, 2006). So in order to meet desired water requirements, there is a need to manage rain water and practice the irrigation techniques that can help to conserve more water and to minimize the water losses. There are many available irrigation techniques that can be used. Among them, micro irrigation method is one of the irrigation techniques that can help farmers to produce crops with minimum water resources as compared to the conventional irrigation methods.

Materials and methods

The experiments were conducted at Barani Agricultural Research Institute (BARI) located within 72° longitude, 32° latitude and 575 m altitude in the district Chakwal, Pakistan from 2013-2014. The climate of Chakwal is semiarid subtropical and the annual rainfall varies from 500-1000 mm most of which falls during monsoon (Fig.1) in the form of high intensity showers. The area also receives winter showers of lesser intensity during December to February. Rainfall if not managed, it quickly evaporates or runs as flash floods into saline sinks. Thus, the starting point of rainwater harvesting is to capture rain water where it falls for purposes of meeting the water needs of that area.

Rainfall data for the last 37 years (1979-2014) was collected to investigate the rain water collected and consumed by the olive plants by establishing micro catchment rainwater harvesting structures. Maximum rainfall occurs during July to September. One of the reasons for the poor utilization of rainwater in rainfed areas like Chakwal is the high concentration of rainfall over a few months (Fig. 1). About 60 percent of the rainfall is received during the south-west

monsoon period of June to September (Table 1).Even this does not fully reveal the concentration of big spells of rains. As a result, the soil saturates, and much of the water flows away if no structures are made to check this flow.

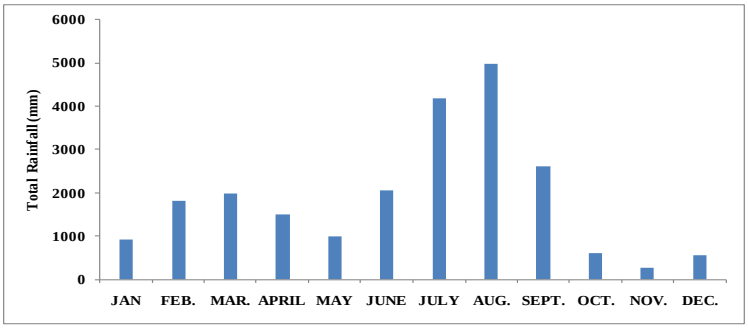


Figure 1. Rainfall Pattern of Chakwal District (1979-2014)

The uneven distribution also creates a situation of long dry periods when cropping is difficult if water is not retained or made available in some other way. In October and November, the weather becomes relatively dry and humidity decreases to some extent. Due to winter rains, the weather becomes more humid; maximum mean relative humidity (75%) was recorded for the month of February.

Table 1: Distribution of Rainfall by Season in Chakwal

Rainfall	***Duration***	***Annual rainfall (mm)***
Pre Monsoon	March-May	20
Southwest Monsoon	June-September	62
Post Monsoon	October-December	7
Winter or north east monsoon	January-February	11
Total	**Annual**	**100**

Source: Met observatory at Soil and Water Conservation Research Institute, Chakwal, Pakistan (1979-2014)

Rainfall if not managed, it quickly evaporates or runs as flash floods into saline sinks. Thus, the starting point of rainwater harvesting is to capture rain water where it falls for purposes of meeting the water needs of that area.
The soils of the experimental area (BARI) are piedmont alluvial plains order: ALFISOL belongs to therpal/satwal/kotli series. The P.H of the soil varies 7.8-8 and field capacity of the experimental area varies from 14-15% by volume and permanent wilting point varies from 4-5% by volume. The soil contained sand (43-55%) followed by silt (49-58%) and clay (8%) and could be classified as sandy loam (Abdul *et al*, 1989). Soil characteristics of micro catchment structures are given in Table 2.

Table 2: Soil characteristics of the micro catchment structures

Characteristics	**0 - 0.15 m**	**0.15 - 0.3 m**
EC (dS/m)	0.3	0.25
Organic matter (%)	0.6	0.33
N (%)	0.8	2
P (ppm)	5	3.4
K (ppm)	138	132
Sand (%)	60	
Silt (%)	30	
Clay (%)	10	
pH	7.68	7.79

Establishment of micro catchments:

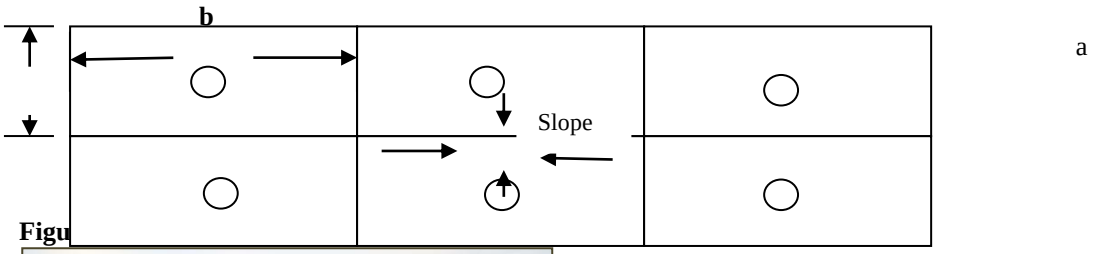
A micro-catchment is a specially contoured area with slopes and berms designed to increase runoff from rain and concentrate it in a planting basin where it infiltrates and is effectively stored in the soil profile. The water is available to plants but protected from evaporation. Three field plots were used to evaluate the performance of micro catchment rain water harvesting techniques on olive (BARI ZAITOON 1) with 18 ft ×18 ft plant spacing. Three

different shapes; square, rectangular, and triangular or V shape (Fig. 2, 3 and 4) and sizes of microcatchments were constructed with 3-5% slope (Table 3) for olive plants at experimental site (BARI), to harvest rainwater.

Table 3: Characteristics of different shapes of micro catchment structures

Shape	Avg. catchment area C (m^2)	Avg cultivated area CA (m^2)	C/CA	Soil type	Avg plant height (m)	Avg Plant canopy (m)	Avg. Slope (%)
V	20	4.6	4.3	Sandy loam	4	1.2	3
Square	28	4.6	6.5	Sandy loam	3	1.2	2
Rectangular	23	4.6	5.0	Sandy loam	4	1.2	4

Data collected in this study included two major components. These are the catchment area (CA) which generates runoff, and the cultivated basin (CB) where the runoff is concentrated, stored and productively used by plants and also the C/CA ratio, Average plant height and canopy (m) and Average slope (%) from each shape of micro catchment structure. micro catchments and is suitable for uneven terrain (Table 3).



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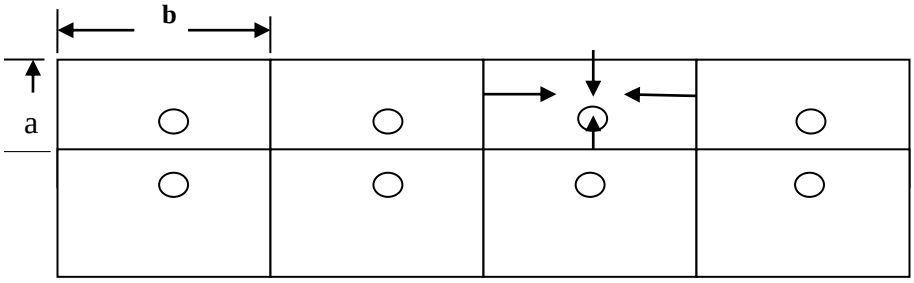

Figure 3. Square shape micro catchment structure

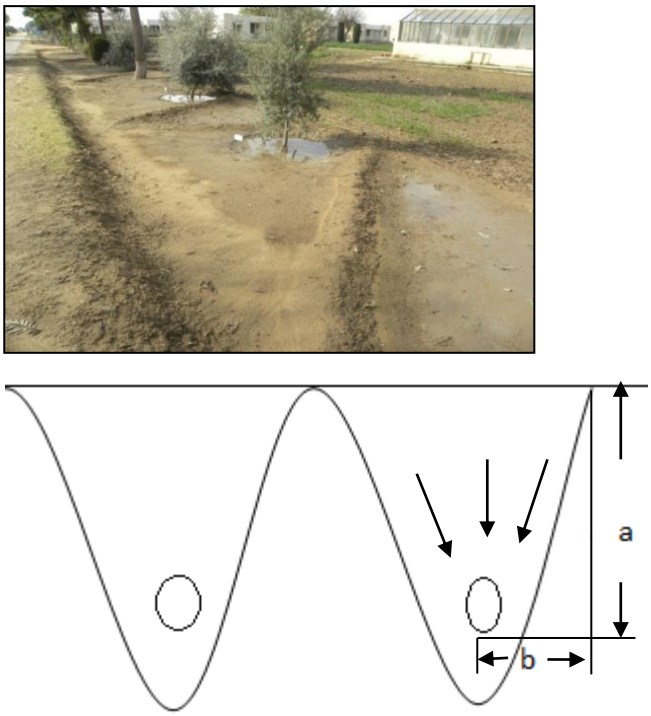

Figure 4. V shape micro catchments

The relationship between the catchment area and the cultivated area, in terms of size, determines by what factor the rainfall will be multiplied (Table 3). For a more efficient and effective system, it is necessary to calculate the ratio between the two if the data related to the area of concern in terms of rainfall, runoff and crop water requirements is available (Moges, 2004).

To monitor soil moisture, three sets of gypsum blocks were installed at three different depths (0.3 m, 0.6 m, 0.9 m) and monitored the behavior of moisture contents in three depths in three different shapes of micro catchment structures for two years (2013 and 2014). Before the installation of gypsum blocks in the field, they were first calibrated by soaking them in the soil tray for three days and continuously taking the data of moisture content along with resistance, and then by using this set of data, charts and equations were drawn (Fig. 5), between resistance and moisture contents. And these equations then were used to monitor moisture contents in the micro catchments.

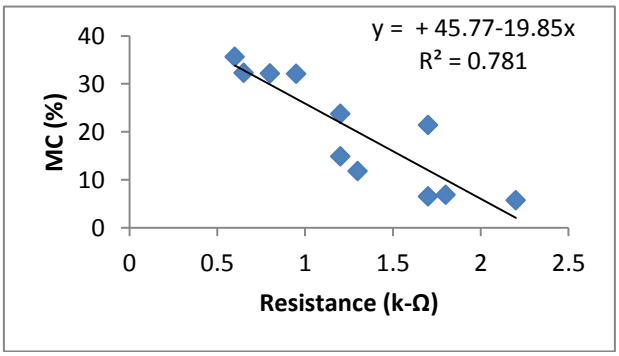

Figure 5. Charts and equation drawn from gypsum block data

Results and discussion

In 2013, 823 mm rainfall is received and in 2014, 770 mm rainfall is received (Fig. 6), that created a large number of runoff. Fig. 6 shows the rainfall distribution pattern in both years.The success or failure of rainwater harvesting depends to a great extent on the quantity of water that can be harvested from an area under given climatic conditions. The threshold retention of a catchment is the quantity of precipitation required to initiate runoff; it depends on various components such as surface storage, rainfall intensity, and infiltration capacity. Table 4 shows the catchment area and water harvested from different shapes of micro catchments.

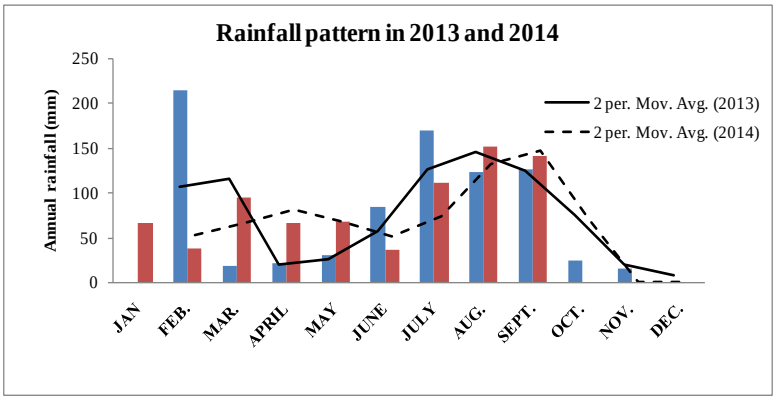

Figure 6. Rainfall distribution pattern in 2013 and 2014

Table 4: Runoff rate (lph) and volume of rainwater harvested (liter) of different micro catchments

Shape of Micro catchment	Catchment area (m^2)	Vol. of rain water harvested (liter)	Rate of runoff (lph)
Rectangular	23	9154	621
Square	28	11144	756
V-shape	20	7960	540

The above calculations showed that square shape micro catchment structure produces more runoff and harvested more rainwater in comparison with rectangular and V shape. But to look at soil moisture status is also very necessary to decide which shape harvest more rain water.

The soil moisture contents distribution in different shapes is shown in Fig. 7, 8 and 9 for the year 2013 and 2014. Field capacity of sandy loam soil is 13% and permanent wilting is 4%, so available moisture content is 9 %. It is reported that more than 70% of olive roots are located in first 60 cm of the soil (Masmoudi *et al*, 2007) .Therefore, effective root zone depth of olive is 0.6 – 0.7 m. Total water requirement of the olive tree is 650mm/year, calculated using CROPWAT v.8 and was in the range as reported by Orgaz and Pastor, 2005. MAD value for olive is 60% that means if moisture content reaches to 62 mm then supplement irrigation through micro (drip/bubbler) irrigation system should apply. Moisture distribution charts (Fig 7, 8 and 9) are showing the moisture status along with rainfall (columns) and arrows in downward direction are the events of supplement irrigations.

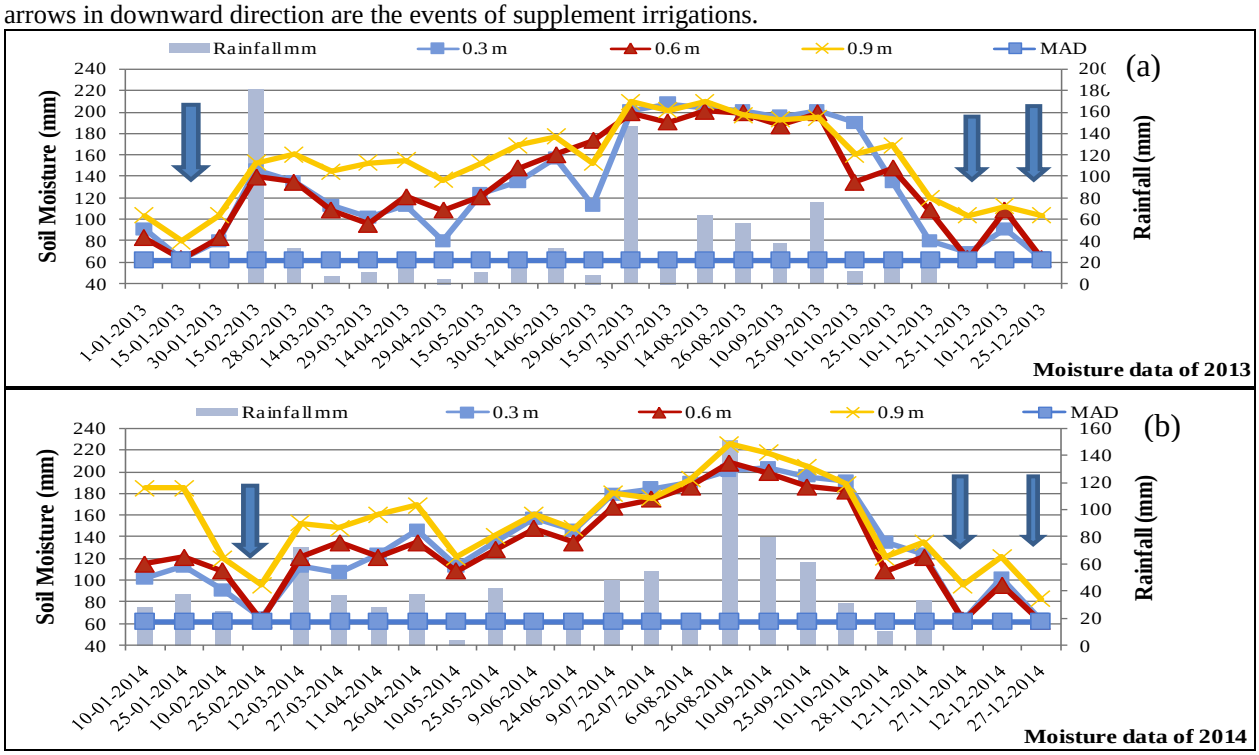

Figure 7. Soil Moisture content distribution in Squar shape micro catchment (a) for the year 2013 (b) for the year 2014

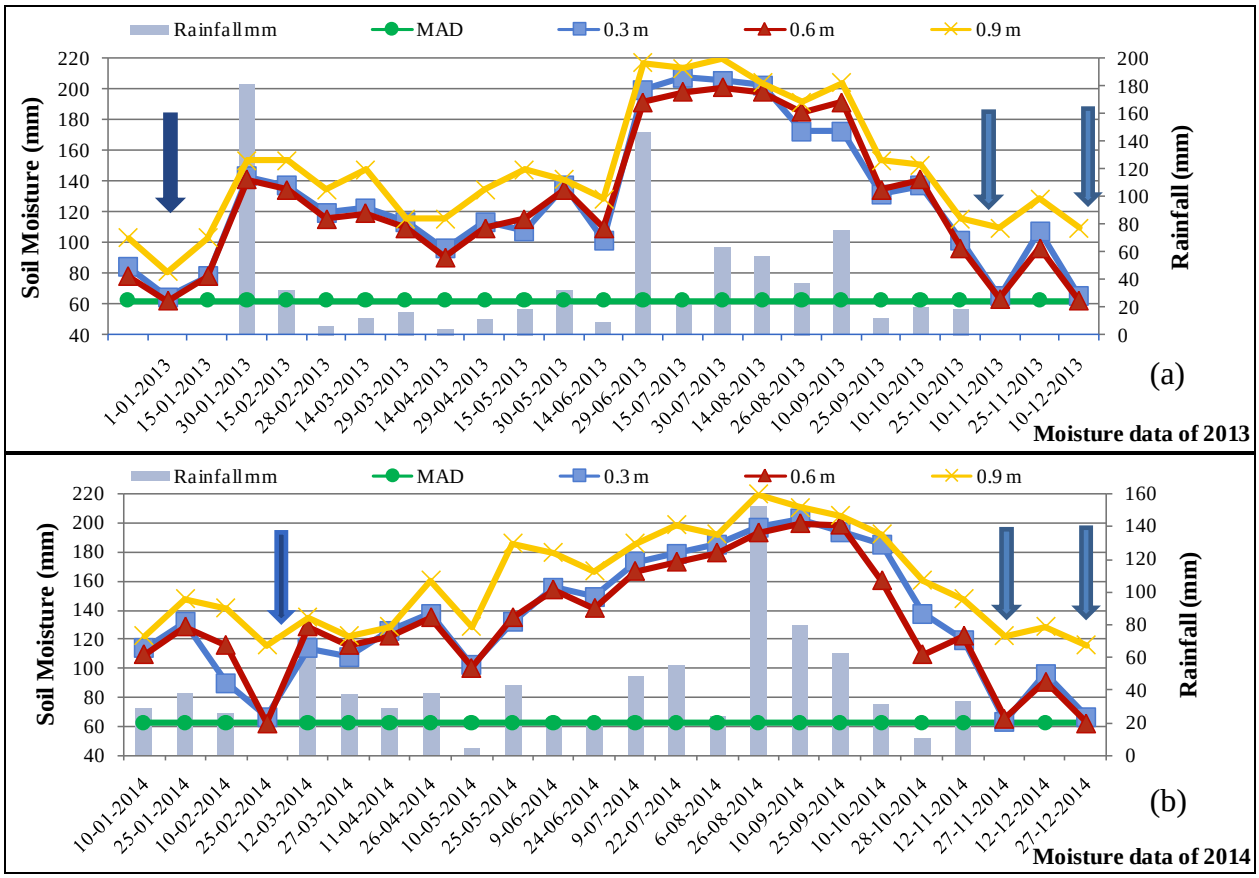

Figure 8. Soil Moisture content distribution in V shape micro catchment (a) for the year 2013 (b) for the year 2014

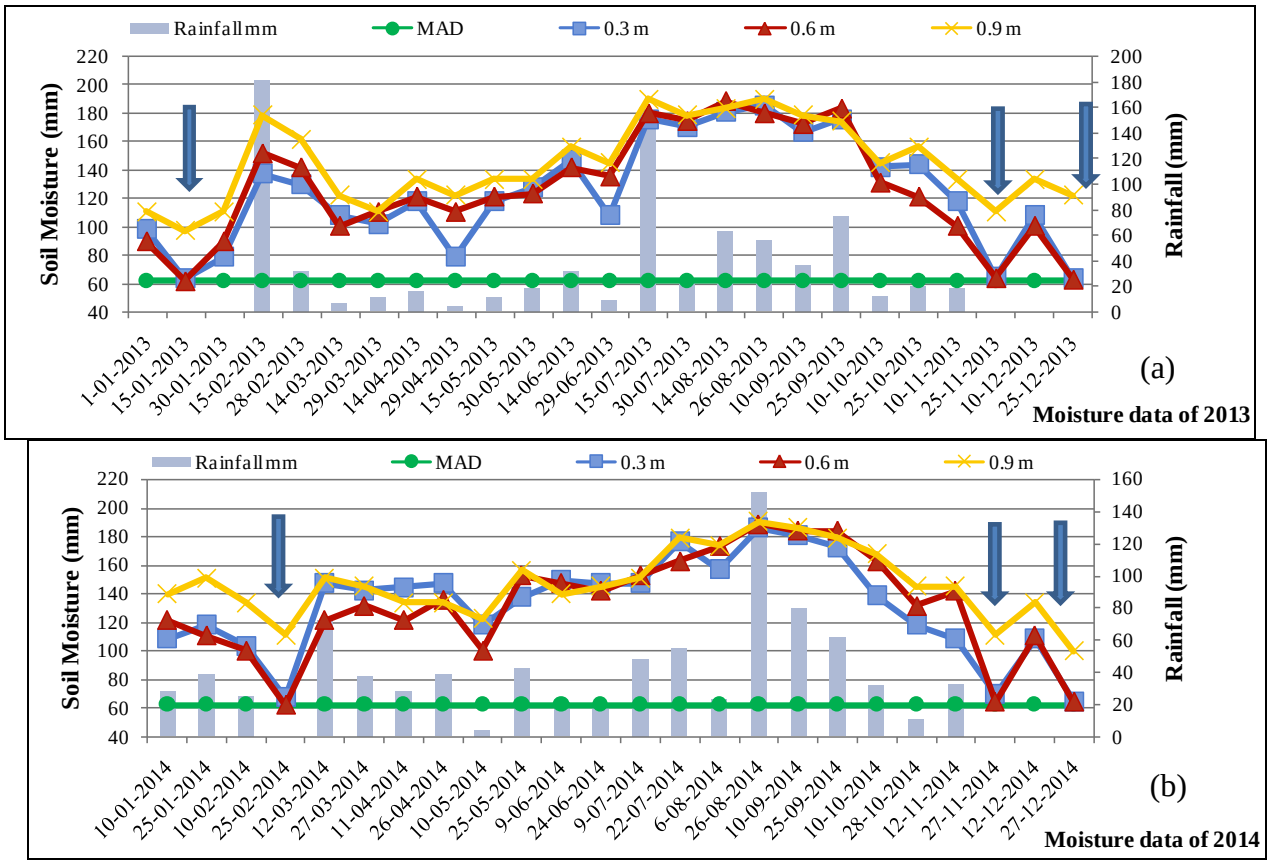

Figure 9. Soil Moisture content distribution in rectangular shape microcatchment structure (a) for the year 2013 (b) for the year 2014

By comparing the above charts (Fig. 7, 8 and 9) it is concluded that soil moistures curves touch the MAD line only at three times that means only three supplement irrigations were required to the olive in winter season. Therefore, micro catchment structures are best suitable to this tarren because they generaetde and harvested water more and only three supplement irrigations were applied to olive plant through drip/bubbler irrigation system when compared with control (traditional) structure. In controled structure less rain water stored in the soil profile and consequntly more irrigations were applied. The soil moisture contents in the above charts (Fig. 7, 8 and 9) three times touches the MAD line in both the years and those events were in winter as there is less rainfall occoured in winter season.

Constructing microcatchments among the olive trees utilized 85% rainwater effectively and saves 88% of water through supplement irrigation using bubbler irrigation method (Table 6). Control practice consumed only 45% (265 mm) of rainfall. Average effective rainfall of 2013 and 2014 was 594 mm from which 505 mm (85%) was used by olive plants in micro catchments. The remaining water 145 mm was applied through supplemental irrigation using bubbler irrigation method, which again saved 60% water as compared to flood irrigation method. In square shape micro catchment large amount of rainwater was stored; therefore less amount of supplement irrigation was applied in square shape as compared to V shape and rectangular shape micro catchments (Table 5(a & b)).

Table 5 (a): Amount of supplement irrigation (mm) and water saving as compared to flood irrigation method for the year 2013

V SHAPE					
Irrigation event	**Date**	**Irrigation Amount (mm)**	**Water applied with bubbler (mm)**	**Water applied with flood irrigation (mm)**	**Water saving (%)**
1	15-01-2013	40	53		
2	25-11-2013	39	52		
3	25-12-2013	40	53		
Total		**119**	**159**	-	**60**
Square shape					
1	15-01-2013	41	55		
2	25-11-2013	40	53		
3	25-12-2013	42	56		
Total		**123**	**164**	-	**59**
Rectangular shape					
1	15-01-2013	41	55		
2	25-11-2013	41	55		
3	25-12-2013	40	53		
Total		**122**	**163**	-	**59**
Control structure					
1	1-01-2013	42	56	105	
2	14-3-2013	44	59	110	
3	29-04-2013	39	52	98	
4	10-09-2013	42	56	105	
5	25-10-2013	45	60	113	
6	10-12-2013	46	61	115	
7	25-12-2013	42	56	105	
Total		**300**	**400**	**750**	

Table 5 (b): Amount of supplement irrigation (mm) and water saving as compared to flood irrigation method for the year 2014

V SHAPE					
Irrigation event	**Date**	**Irrigation Amount (mm)**	**Water applied with bubbler (mm)**	**Water applied with flood irrigation (mm)**	**Water saving (%)**
1	25-02-2014	39	52	-	
2	27-11-2014	39	52	-	
3	27-12-2014	38	51	-	
Total		**116**	**155**	-	**61**
Square shape					
1	25-02-2014	39	52		
2	27-11-2014	42	56		
3	27-12-2014	41	55		
Total		**122**	**163**	-	**59**
Rectangular shape					
1	25-02-2014	41	55		
2	27-11-2014	39	52		
3	27-12-2014	39	52		
Total		**119**	**159**	-	**60**
Control structure					
1	10-02-2014	44	58	109	
2	25-02-2014	44	58	109	
3	10-05-2014	39	53	99	
4	8-06-2014	45	60	113	
5	28/10/2014	39	52	98	
6	27-11-2014	44	59	110	
7	27-12-2014	39	53	99	
Total		**294**	**392**	**735**	

Application of right quantity of irrigation water at right time through an appropriate irrigation method not only saved water but also increased yield of the olive plant. Yield increase of 6-9% was recorded in microcatchments constructed among olive plants as compared to traditional farmer practice (Fig. 11). As square shape micro catchment stored large amount of rainwater (Fig. 7), therefore higher yield was recorded in this shape. Yield increase of 8%, 6% and 7% was recorded in square shape, V shape and rectangular respectively when compared with traditional practice in 2013 and yield increase of 9%, 6% and 8% was recorded in square, V and rectangular shape respectively in 2014. The yield was less in 2014 because of alternate bearing of olive.

Results of fruit yield increase are very relate with Sikaoui *et al*., (2014), that watering through micro irrigation saves 71% of water as compared to control practice (farmer practice) in olive. This control practice leads to a water stress with low water use efficiency despite the high amount of irrigation water applied. Previous studies showed that the increased production of olives is based on the water use efficiency (Michelakis, 1998) which strongly depends on soil moisture during sensitive phenological stages (Mennah *et al*., 2012). Nevertheless increasing irrigation quantities over and above the plant water requirements will not improve yields and will become a financial burden. It has also been shown that over irrigation had not induced any beneficial impacts on the olive tree. To the contrary, it can cause more harm than benefit. Deterioration of the root system and the whole tree due to water-logging is a very common outcome of excessive soil water. Fruit split caused by water swelling is another example of negative impacts from excessive water application by irrational excess irrigation at the final stages of fruit ripening.

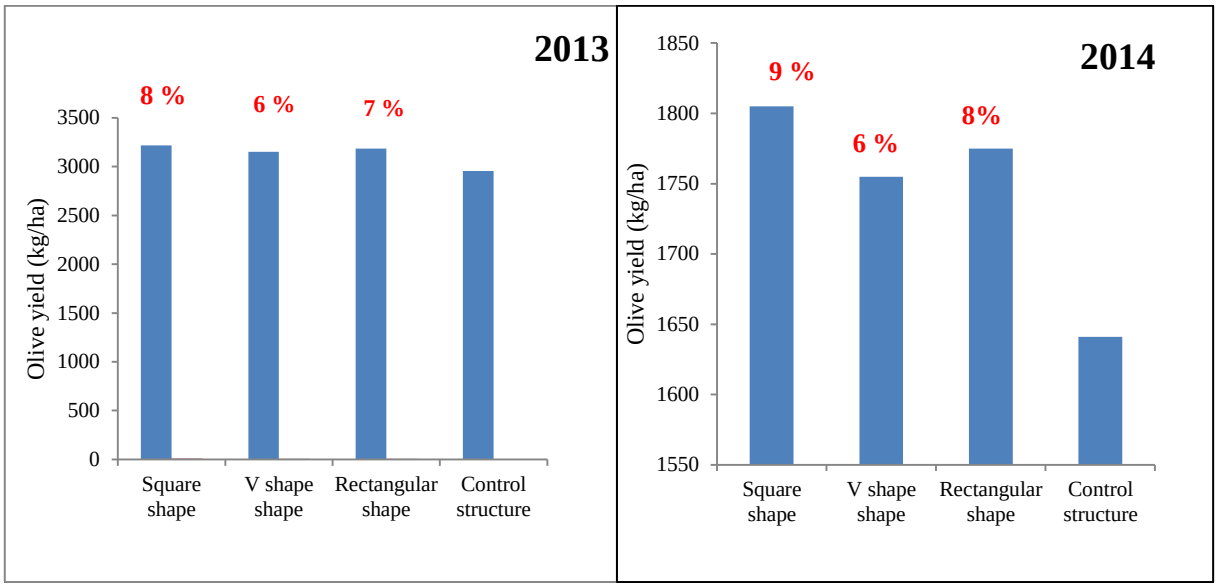

Figure 11. Comparison of yield increase of olive planted in different shapes of microcatchment structures from control farmer practice (2013 and 2014)

Conclusion

The study has shown that by analyzing the soil moisture distribution patterns in three shapes at three different depths and comparing it with control structure it is concluded that there was only three supplement irrigations were applied through micro irrigation system (drip/bubbler irrigation system) in winter season when there was not sufficient rainfall to meet crop water requirements in micro catchment structures. Even in warm weather, no supplement irrigation was provided to the plants. Therefore by constructing micro catchments among olive trees save 88% irrigation water and increase yield from 6-9 % when compared with traditional practice. Square shape micro catchment structures were best suited to this terrain because it stored and used large amount of rain water effectively. Micro catchment rainwater harvesting is the best technique to conserve rain water especially in rainfed areas as they are simple to construct and can be developed easily using local materials and manpower. Drip and bubbler irrigation should be used as supplement irrigation technique in micro catchments. It is also concluded that to give more water than plant's requirement in flat sowing, more water is wasted and in flood irrigation when applying large amount of water it leach down the micro and macro nutrients and all the minerals desired for plant growth and ultimately the loss of these nutrients and minerals will effect on olive fruit yield (quantity and quality). Also disease attack on the plant and due to standing water in the field it damaged the root of the plant.

Acknowledgments

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GIS-based approaches for land evaluation of sustainable cultivation of olive trees

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Abstract

Land evaluation is a well-known procedure that allows predicting the potential use of the land, and it's a strategic instrument for planning investiments in the agricultural sector and promote rural development. The framework for this procedure was conceptualized by FAO since 1976, and revised under the new advances in information technology in 2007 and 2012, introducing new ecosystemic approach of Global Agro-Ecological Zoning. The increasing availability of data related to land qualities and to the response of crops, along with the availability of GIS applications, makes possible an approach to planning in agriculture that takes into account the different scenarios and helps to make the best possible choice.Conceptual methodology and GIS-based technical approaches were discussed step by step, under different methods, with particular focus on the thematic data necessary to implement a land evaluation for sustainable cultivation of olive tree in Pakistan. Land requirements regarding Climatic, Soil, Topographic parameters and related suitable/not suitable classes actually used at local/regional and world level are reported and considered under the data actually available in that Country. A quantitative transformation of suitability classes trough "rating" system is proposed for the possible future evaluation of the suitability of this kind of crop.

Key words: Land evaluation; GIS; soil, olive, limitations, land requirements

Introduction

Land evaluation may be defined as "the process of assessment of land performance when the landis used for specified purposes" (FAO, 1985), or as "all methods to explain or predict the use potential ofland" (van Diepen *et al*., 1991). Once this potential is determined, land-use planning can proceed on arational basis, at least with respect to what the land resource can offer (FAO, 1993). Thus, landevaluation is a tool for strategic land-use planning. It predicts land performance, both in terms of theexpected benefits from and constraints to productive land use, as well as the expected environmentaldegradation due to these uses (Rossiter D.G., 1996).The principles of qualitative Land Evaluation for agricultural use were first established by FAO (1976) in its Soil Bulletin n. 32 "A framework for land evaluation", with a first revised version introducing the concept of "sustainable use of land resources" and the related use of georeferenced databases (FAO, 1995), and a final revision and upgraded approach (FAO, 2007).

More complex evaluation methods were further developed under an ecosystemic outlook, like Agro-Ecological Zoning AEZ (FAO, 1996), and transposed into a GIS model applied at global and regional scales (IIASA/FAO, 2012) to quantify actual end potential yield (Global AEZ). GAEZ uses a quantitative (poorly deterministic) approach by assigning numerical ratings to several parameters describing soil, climate and other land properties. Advances in computer technology by database and GIS tools introduced many different and new methods in order to manage land evaluation in agriculture. Indeed, nowadays we can talk about GIS customized models that follow different approaches, especially in the a) management of different data sources (soil, land use, climate, etc,) by different conceptual data structures and models, and b) spatialization methods and management of the uncertainty of data according to the survey different scales. GIS applications were developed and used as Decision Support Systems (DSS) or qualitative-quantitative mixed models for land evaluation, as Knowledge-based and Automatic systems.

Previous experiences of land evaluation for olive trees in Pakistan

The interest inolive cultivationin Pakistanappearedin the last fewyears, it hasled to the creationofaninternational cooperation projectwith theIstituto Agronomico per l'Oltremare (IAO) titled "Promotion of the production and marketing of olive oil" funded by the Italian Directorate General for Development Cooperation-Ministry of Foreign Affairs (MAE-DGCS), as part of the agreements between Pakistan and Italy. In the context of the Project, a first land evaluation of the whole Country and of some pilot areas (14 districts) was carried out (Del Cima R. e Urbano F. 2008, 2009). This was a preliminary investigation which used only some land characteristics and qualities, as topographic (slope, elevation, aspect), climate (average annual rainfall, minimum and maximum monthly temperature); soil data were not used with a direct interpretation of the Soil map 1:250.000 because of the poor level of information contained in the map legend, but just the "bareness index" (i.e. the surface without any cultivation) was

taken into account, as a predictor of not suitable area at all (figure 1). All the data collected were structured as GIS layers and matched with a Boolean logic. This kind of work could be considered as a preliminary approach, but the quantity and quality of land information used was too low to obtain results useful for planning this kind of land use.

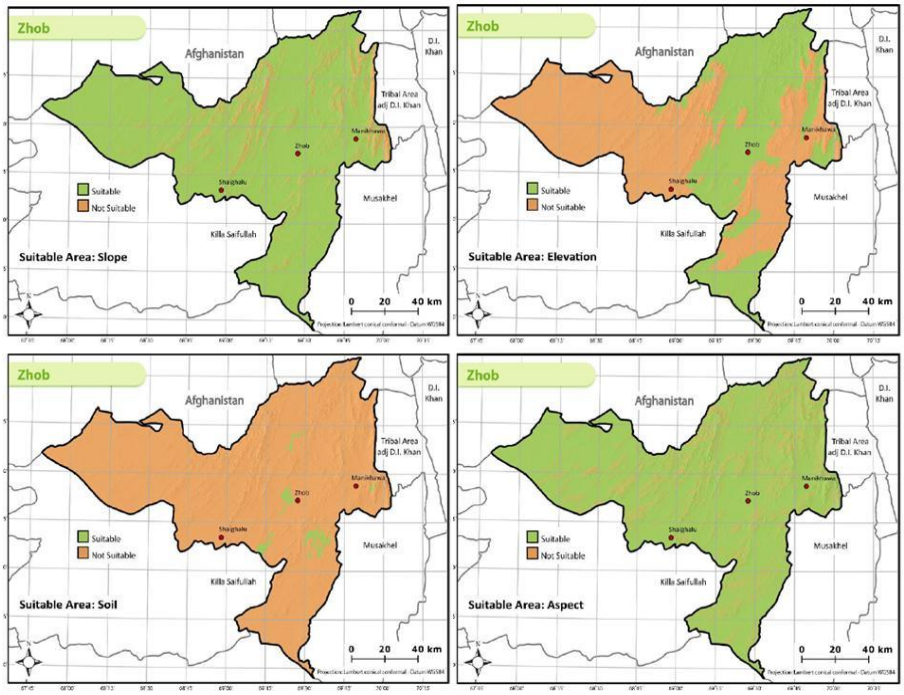


Figure1. Example of maps of suitable areas for the Zhob District according to bare soil, slope, aspect and elevation land characteristics (after Urbano F. and Del Cima R., 2009).

The principles of land evaluation

Despite further studies have moved towards quantitative and deterministic models of land assessment and have so made FAO's initial approach outdated and superseded (for a comprehensive review see Manna *et al*., 2009), in the present paper we will adopt FAO's model as it is a quite simple method, suitable to be adopted as an example of how the crop characteristics and the land properties interact in determining the productive performance.

Indeed, whichever is the methodology adopted, the land evaluation consists in the attempt to predict, by means of a more or less deterministic model, how the crop will suite to land characteristics (some of which can be modified with farming practices) as well as it will respond to human input.

Therefore, for the purpose of rural development and planning in agriculture, it is important to spend efforts in acquiring and organizing high-level knowledge of both crop behaviour and of land properties.

FAO's approach to land evaluation (taken here as both a reference and an illustrative method) is based, in brief, on four main steps:

1) Establishing the requirements of the land utilization type (LUT) of interest
2) Mapping the land units in the area to be evaluated and assess the qualities of each of them
3) Comparing LUT's requirements with land qualities and determine the degree of matching , which leads to classify the land units in current suitability for the LUT
4) Evaluating the potential suitabilit, after major improvements have been completed where necessary

This approachhasageneral validityandcan be adapted toall possible typesofLUTs.

STEP 1: Establishing the LUT's (olive trees) requirements

Establishing the requirements of a generic crop may concern:

1. Conditions affecting crop growth and productivity, which is determined by both primary productivity (= availability of energy for the photosynthetic process) and soil and climate constraints
2. Climate requirements: heat availability (mean annual temperature can in most cases be considered a good proxy indicator), total rainfall and seasonal distribution, duration of cold season (induction of dormancy), intensity of frosts and duration of frost-free period…
3. Soil requirements: depth, water holding capacity, water table depth, texture, salinity, pH, nutrient content, internal drainage/permeability,

4. conditions affecting the possibility of (mechanized) cultivation and/or irrigation supply: workability, slope, rockiness and stoniness, flood hazard

In qualitative land evaluation models (such as the FAO's ones) crops' requirements are expressed in classified (discrete) values. For instance, optimal depth of soil for olive trees could be >120 cm; moderately good depth could be 80 to 120 cm; poor depth could be 50 to 80 cm and unsuitable depth <50 cm. In deterministic models, where the main (sub) processes ruling plant growth and yield follow (or try to follow) the fundamental biophysical laws of agroecosystem, crops' requirements tend to become physiological parameters, expressed by numerical values, which interact, through numerical algorithms, with analogous parameters describing the physical behaviour of the soil-atmosphere domaine. After the above general considerations, we will address in detail the specific land requirements and constraints for olive tree cultivation. Most olive-growing areas lie between the latitudes 30◦ and 45◦ north and south of the equator (figure 2), although in Australia some of the recently established commercial olive orchards are closer to the equator than to the 30◦ latitude and are producing a satisfactory yield; this may be because of their altitude or for other land specific characteristics.

Figure 2. Geographical distribution of areas actually used for olive cultivation in the World.

It is widely recognized and shared, in the scientific literature as well as in the agricultural practice, that the olive tree finds its ideal climatic conditions in the areas around the Mediterranean Sea, which have relatively cool winters with frost seldom occurring, hot dry summers and an average annual rainfall of 800 mm or less. In rainy-summer regions, high humidity and temperatures can aggravate the onset of pests and diseases. Different Authors found more specific crop requirements. Below is a short review of what can be found in the literature on the matter.

According to FAO (1977), the olive crop requires low winter temperatures to enter the stage of vegetative rest and to initiate flower development. On the other hand, frost can seriously damage olive trees (especially the young ones), the young shoots and inflorescences, resulting in serious losses. Most of the cultivars suffered severe frost damage, to death, when exposed to temperatures of -15°C but some tolerant cultivars can survive also at lower temperatures. The olivegrows well also on poor soils but it does not tolerate the poorly drainedor waterlogged ones, since it is susceptible to asphyxia and to root diseases. Production on shallow soils will be disappointing. Coarse-textured soils with poor water retention capacity will require intensive management in terms of irrigation and nutrition. Soil pH (in KCl) should be above 5.5, and preferably near 6.5. Irrigation, preferably by means of drippers or microsprinklers, can be indispensable in arid or semi-arid regions.
According to Therios, (2009), the main environmental conditions affecting production of olive concern:

i) heat availability
ii) chilling units
iii) low temperatures and frost
iv) soil texture
v) soil structure
vi) soil porosity

vii) kind of soil horizons
viii) retention of soil water
ix) waterlogging

Costantini (2009) found, for olive trees grown in Mediterranean conditions, the following soil characteristics as strongly affecting olive tree production:

i) depth of water table
ii) soil classification (Vertisols or other Orders)
iii) Salinity
iv) AWC
v) internal drainage

As one can argue from the examples reported above, researchers, based on their own experience, do not always agree on the characteristics to be considered when assessing olive's requirements. This is the reason why crop requirements should be set on the basis of local knowledge of crop response to environmental conditions. Experiences found in literature from similar areas can be useful but must be very carefully scrutinized in order to avoid dramatic mistakes. So "local knowledge" is a focal issue for land evaluation and requires the availability of a network of experienced staff (agronomists, soil scientists, agroclimatologists) able to carry out experiments at sites under controlled conditions (experimental farms), so as to capitalize on the widespread knowledge from the everyday experience of the farmers in the area.

STEP 2: Mapping the land units

Land unit is a mapped area of land with relatively homogeneous characteristics with respect to the specific destination. Land characteristic are attributes that can be measured or estimated. Examples are slope angle, rainfall, soil texture, available water capacity, etc. Land qualities are complex attributes which come from the interaction between different characteristics. Examples are moisture availability, erosion risk, flooding hazard, nutritive value of pastures.
To map the land units in the area to be evaluated and assess their qualities is a complex task, which requires the availability of acomplete inventory of natural resources, including (non exhaustive list):

i) Soil map and related databases describing the qualities of soils
ii) Availability of supplement water for irrigation
iii) Climatic maps and related data (at least daily recordings)
iv) Topography (steepness, aspect, shape of slopes, curvature, Topographyc Wetness Index, etc.)

The collection of these data may require survey activities (soil survey) and acquiring data from different sources: weather station, remote sensing, digital terrain model (DTM) and so on.Whilst crop requirements (in FAO's model) are expressed in classified values, in order to ensure flexibility land characteristics should be acquired and stored as far as possible as numerical values. Fixed classes for land characteristics may fit well with classified values of requirements for some crops, but may not fit for many other crops.

In the case of a specific land evaluation project (such as it could be for olive trees) and when this information is not yet available, the major constraints (e.g. elevation, steepness, latitude) can be helpful in delimitate the area of interest from which to collect data. Proceeding by successive approximations, the focus can be set on the areas potentially more suitable, where to concentrate more intensive efforts in data collection. To carry out a reliable land assessment for olive cultivation, information concerning the main physical factors of agro ecosystem are needed, with geo-referenced databases and specific density and quality of the data to be collected. In the further paragraphs we try to explain in detail some proposals to manage a successful land evaluation procedure for olive tree cultivation.

Soil database, maps and derived properties

Soil map and related database should correspond to a soil information density at least at a reconnaissance level (1:250,000); according to Dent & Young (1981) (table 1) the density of observation sites (pedons or hand auger obs) should be at least of 1 per square centimetre of map, which corresponds, at the scale of 1:250,000, to 6.25 km2. In order to evaluate the quality of a soil survey, it can be useful to distinguish between "quality pedons" and more speditive observations. Quality pedons correspond to soil profiles which are described in detail after excavation and whose horizons are sampled and analyzed in lab to get a more or less complete physical and chemical characterization. Quality pedons are mainly used to establish the differential properties of soil types. Speditive observations consist in describing (more or less in detail) samples taken by a hand auger or just taken from the soil surface. Such kind of observations is mainly used to establish the geographical distribution of soil types.In a good-quality soil survey, the ratio between these 2 kinds of observations should be about 1 to 10, that means 1 quality pedon per 10 speditive obs.

Soil description in the field and further recording in a proper database should be carried out according to the methods and system of coding of the Guidelines for soil description (FAO, 2006).

Table 1. Soil survey intensity versus sampling density and progress rate of mapping activity (after dent & Young, 2981)

Survey type	Scale	1 cm on the map = field surface	Observation density	Progress rate per 20 days
Very high intensive	1:5,000 1:10,000	0.25 ha 1.00 ha	1/0.5 ha 1/2.5 ha	500 ha 800 ha
High intensive	1:20,000 1:25,000	4.0 ha 6.25 ha	1/8 ha 1/12.5 ha	1250 ha 1500 ha
Medium intensity	1:50,000	25 ha	1/50 ha	75 km^2
Low intensity	1:100,000	1 km^2	1/km^2	200 km^2

Harmonisation and correlation should be under supervision of a Soil Survey Office at country level. At least (for the specific porpoise of land evaluation for olive trees) to the map a database should be related, containing information on the following soil properties:

i) water logging
ii) soil depth
iii) horizons properties (kind, texture, structure, porosity, skeleton, available water capacity, salinity)
iv) depth of water table
v) soil classification
vi) internal drainage
vii) soil permeability
viii) surface stoniness

Relating to the above listed soil characteristics and qualities, geostatistical methods can be used to generate maps and to assess the uncertainty of the predicted values as an alternative to a detailed survey (Caridad-Cancela *et al*., 2005), giving a summary of variogram data for a variety of soil properties McBratney and Pringle (1997). Moreover, Digital Soil Mapping (DSM) methods described by McBratney *et al*.(2003) and McKenzie *et al*.(2008) were developed a set of models derived from statistical relationships between soil data and various environmental covariates, which are derived landscape features (elevation, aspect, slope, curvature, relief intensity, topographyc wetness index, etc.), land use/land cover, parent material/lithological maps, prepared as continuous data themes – rasters in GIS terminology.

It differs from traditional soil mapping in that the outputs are usually single soil attributes (e.g. pH, soil depth) predicted for individual cells (pixels) in the raster image. Key advantages of DSM are that(i) its statistical models are quantitatively based, flexible and repeatable, (ii) it can be applied rapidly across large areas, and (iii) estimates of uncertainty can be routinely produced as a guide to the reliability of the DSM outputs (Harms *et al*ii, 2015). DSM has become the preferred method for many soil mapping applications (e.g. Mansuy*et al*.,2014; Gooley *et al*., 2014) and is the technique being adopted to deliver a soil map of the world (Arrouays *et al*., 2014). DSM has progressed beyond beings imply a technique for predicting soil attributes, and is now used as a tool for assessing soil functions, processes and capability – i.e. digital soil assessment (DSA), (Carré *et al*., 2007). DSA translates DSM outputs into risk-based, spatial decision making aids (McBratney *et al*., 2012).

Agricultural water resources data

Availability of water for irrigation supply it's an important type of information to be known, as well as the amount and quality of water available for irrigation; presence of a network of channels for adduction and distribution; training of farmerson theproper techniques. Map of land suitability for irrigation, based on actual constraints, it's an additional information that if present, it can be added directly as additional layer in the land evaluation process.

Climatic databaseand thematic maps

Climatic maps require a network of meteorological stations where data are available on a long-term period (at least 30 years). In general, for large plains where spatial variability of climate is low, 1 station per 400 km2 is considered to be a satisfactory density. In areas where the topography plays an important role in determining the climate variability, especially the rainfall regime, spacing between stations must be carefully set on the basis of the local interaction between atmospheric circulation and orography (main and secondary mountainous chains; width and orientation of valleys and so on). Climatic data collected in a meteorological station have only a punctual extent. To build a climatic map it is indispensable to assign each station a bi-dimensional domain. Usually this is carried out by means of spatial interpolation techniques. Many theoretical and practical approaches to spatial interpolation are available from literature. Among these, it is worth mentioning the recent work of Antolini *et al*. (2015), which used, for temperature, a daily best-performing detrending procedure, followed by the interpolation of regression residuals by means of a modified inverse distance scheme, accounting for orographic barriers. Elevation, urban fraction and

topographic position are the geographical proxy parameters used for detrending. The same scheme, without detrending, was used for daily precipitation. All data were spatially interpolated on a high-resolution digital elevation model, and then averaged on a triangulated irregular grid with variable resolution depending on topography. As example, some climatic suitability evaluation at continental scale realized by International Center for Agricultural Research in the Dry Areas (ICARDA) inside the Research Program on Dryland Systems (http://geoagro.icarda.org/en/) are reported in figure 3 and 4.

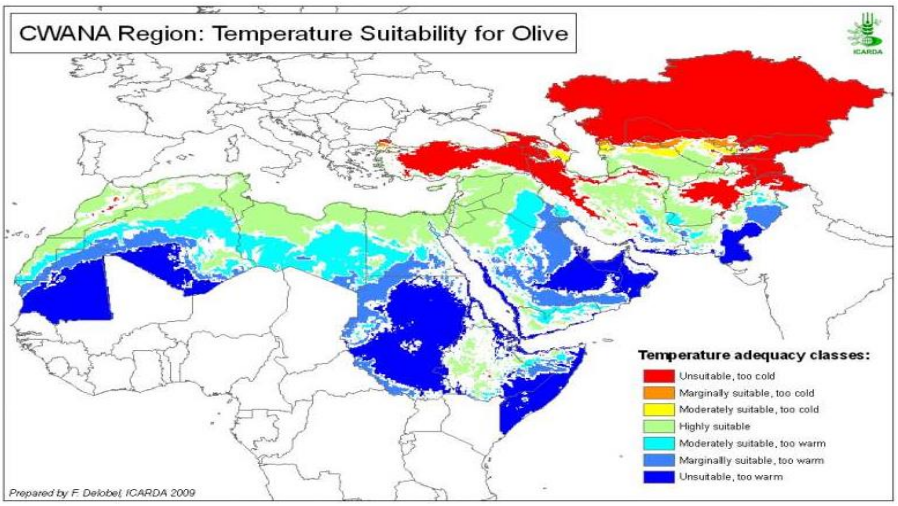


Figure 3. Suitability of the mean annual temperature for olive crops in the Central and West Asia and North Africa region (CWANA): Map of the Temperature Suitability for Olive (2008). Temperatures are classed as follow: < 13C: Unsuitable, too cold; 13-14C: Marginally suitable, too cold; 14-15C: Moderately suitable, too cold; 15-22;C: Highly suitable; 22-24C: Moderately suitable, too warm; 24-26C: Marginally suitable, too warm; >26C: Unsuitable, too warm.

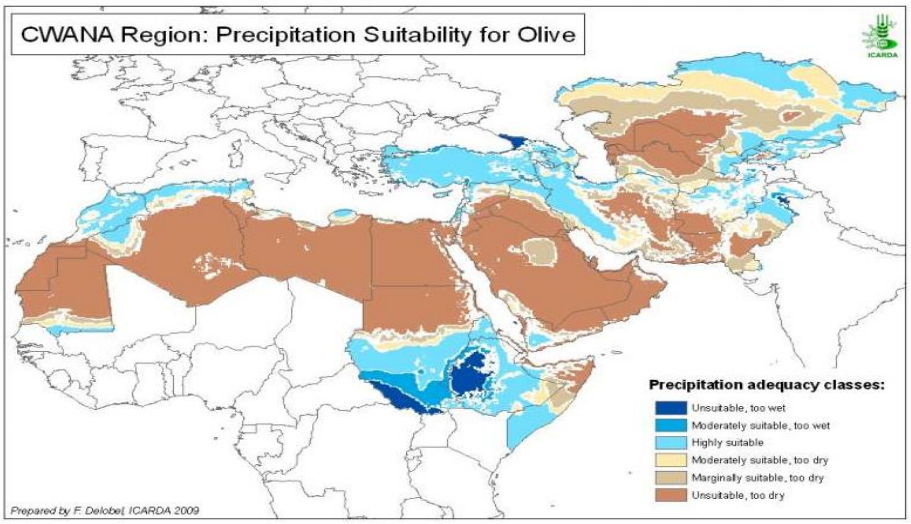


Figure 4. Suitability of the annual precipitation for olive crops in the Central and West Asia and North Africa region (CWANA): Map of the Precipitation Suitability for Olive. Precipitation classes are the following: < 150mm: Unsuitable, too dry; 150-225mm: Marginally suitable, too dry; 225-300mm: Moderately suitable, too dry; 300-800mm: Highly suitable; 800-1100mm: Moderately suitable, too wet; 1100mm: Unsuitable, too wet

Topography

The Global Digital Elevation Model Version 2 (GDEM V2) was released by The Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA) on October, 2011 (NASA Jet Propulsion Laboratory, 2011). This kind of product, a 30-meter pixel wide DEM, it's organized and free distributed with postings and 1 x 1 degree tiles for the whole World coverage. The errors reported

are very low (Tachikawa *et al*ii, 2011), both for horizontal and vertical resolution, and also for the reduction of noise due to "artifacts" and anomalies (water bodies, tree coverage, etc.).The GDEM V2 is very powerful DEM to modelling the land and extract morphometric derived indicators. Indeed, many topographic features and layers could be developed starting from a Digital Elevation Model, from the basic to be used in a Land Evaluation general procedure, to particular and specific useful as "covariates" soil properties predictors with Digital Soil Mapping techniques, are reported in the list in Table 2.

Table 2. List of principal basic and specific parameters thet could be extracted by a DEM useful for general Land Evaluation procedure (*) and to predict soil properties (**) with DSM techniques

Type of parameter derived from DEM	*Data source and description*
Elevation (*) (**)	DEM produced elevation of the land surface
Slope (*) (**)	DEM/ maximum rate of change between cells and neighbours
Aspect (*) (**)	DEM/Direction of the steepest slope from the north
Plan curvature (**)	DEM/ DEM/is perpendicular to the slope and affects the convergence and divergence of flow across the surface
Vertical curvature (**)	DEM/is parallel to the slope and indicates the direction of maximum slope. It affects the acceleration and deceleration of flow across the surface
Mean curvature (**)	DEM/mean vectorial value of the plan and vertical curvature
Flow accumulation (**)	DEM/ Number of upslope cells
Slope-length Factor (**)	DEM/(calculates the slope length as used by Universal Soil Loss Equation)
Convergence Index (**)	DEM/ similar to plan curvature but does not depend on absolute height differences.
Stream Power Index (SPI) (**)	DEM/ can be used to describe potential flow erosion and related landscape processes
Topographic Position Index (TPI) (**)	DEM/the difference between the elevation at a cell and the average elevation in a neighborhood surrounding that cell
Topographic Wetness Index (TWI) (**)	DEM/ Calculates slope and specific catchment area based Compound Topographic Index. **TWI** = ***ln (As/tan β)***: where ***As*** is upslope catchment area and ***β***is the slope.
Direct sunlight insolation (1yr) (**)	DEM/ Calculates potential incoming solar radiation (insolation) calculated in GIS (SAGA)
Mid-slope position index	DEM/covers the warmer zones of scope
Multi-resolution index of valley bottom flatness	DEM/ Calculates the depositional areas
Distance to channel network	DEM/calculates the distance to the channel networks
Valley depth	DEM/relative position of the valley

STEP 3: Comparing LUT's requirements with land qualities

The comparison between crop requirements and land qualities determines the degree of matching , which leads to classify the land units in current suitability for the LUT. The degree of matching (= how much the crop requirements are satisfied by land qualities) was fixed byFAO (Table 3).

Table 3. Suitability classes, coding system, management and limitations (after FAO 1976, mod.)

Code	*Suitability Class*		*Limitations and Management*
S	SUITABLE		The land can support the land use indefinitely and benefits justify inputs
	S1	Highly suitable	Land without significant limitations.
	S2	Moderately suitable	Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity

	S3	Marginally suitable	Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production are increased so that this cost is only marginally justified
N	NOT SUITABLE		Land that cannot support the land use on a sustained basis, or land on which benefits do not justify necessary inputs
	N1	Currently not suitable	Land with limitations to sustained use that cannot be overcome at a currently acceptable cost
	N2	Permanently not suitable	Land with limitations to sustained use that cannot be overcome

Costantini (2009) proposed, for olive trees grown in Mediterranean conditions, the following matching table (Table 4), concerning only the soil parameters.

Table 4. Matching table of soil suitability for olive tree cultivation (after Costantini E.A.C., 2009)

Parameter	Suitability			
Quality and characteristics	Very suitable (S1)	Suitable (S2)	Not very suitable (S3)	Not suitable (N)
Water table depth (cm)	> 100	> 100	> 100	< 100
Classification	No Vertisols	No Vertisols	No Vertisols	Yes Vertisols
Electrical conductivity dS/m (1 m)	< 1	1–2	3–4	> 4
AWC (mm/100 cm)	> 110	110–70	69–30	< 30
Internal drainage	Good, or moderate, or somewhat poorly drained if runoff > average, or somewhat poorly drained if runoff = average and skeleton ≥ 35%	Sometimes excessive, or somewhat poorly drained if runoff ≥ average or skeleton ≥ 35%, or somewhat poorly drained if runoff = average and skeleton ≥ 35%	Excessive, or imperfect, or poorly drained if runoff > average and skeleton ≥ 35%	Poorly drained and very poorly drained

When such a table is applied on a specified area, each land unit is assigned a suitability class, according to its characteristics. The most limiting factor is the one determining the overall suitability. If the case, one can evaluate the potential suitability, that is the suitability class after major constraints have been removed by means of improvements (extraordinary practices).

GIS-based applications for dynamic generation of potential suitability maps

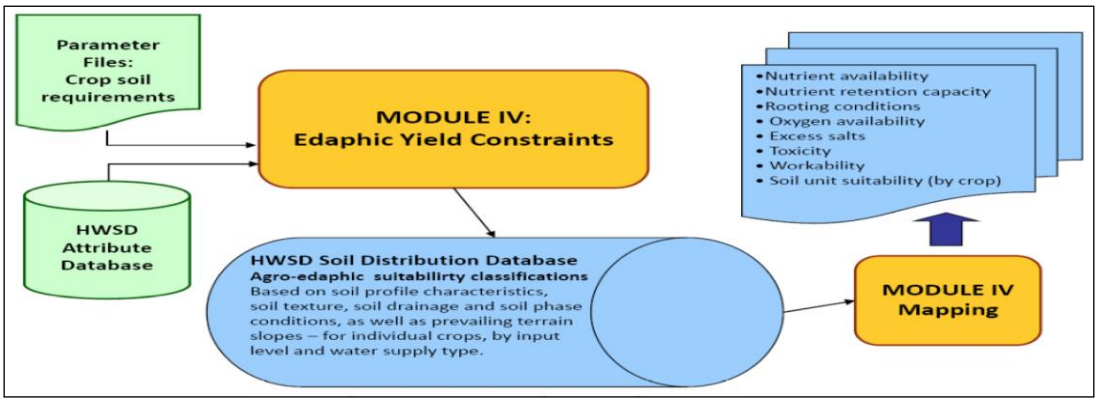
Planning in agriculture needs a dedicated Geographic Information System, i.e. an environment in which map information and associated databases are information that could be managed with a) semi-automatic procedures that allow to generate dynamic maps simulating several scenarios; b) managequality classesofland suitabilitywithquantitative systems, assigningscores (ratings) to thebio-physical considered variables(climate, soil, topography, etc.) withinthe classes themselves(ie S1: 100-80, S2:80-60, etc.), according to the systemproposedby the GAEZ methodology (IIASA/FAO, 2012) (table 5 and figure 5).

Table 5. Example of matching table extracted from the Global Agro-Ecological Zoning model related to the rating assigned to soil parameters (Texture class, Nutrient availability class, Rooting conditions). This table was build following the structure of soil and land use database

Texture requirements		Nutrient availability from loamy sand	Nutrient availability from sand	Rooting conditions from clay (heavy)	Rooting conditions from silty clay	Rooting conditions from clay (light)
Unit		-	-	-	-	-
Soil Quality (SQ 1-7)		1	1	3	3	3
Constraint Level		%	%	%	%	%
CROP_ID	CROP	NUTR_12	NUTR_13	ROOTING_01	ROOTING_02	ROOTING_03

17	Chickpea	70	30	90	100	100
18	Cowpea	70	50	90	100	100
19	Pigeonpea	70	50	90	100	100
20	Dry_pea	70	30	90	100	100
21	Greengram	70	50	70	100	100
22	Soybean	70	30	90	100	100
23	Rape	70	30	90	100	100
24	Groundnut	70	50	70	100	100
25	Sunflower	70	30	90	100	100
26	Oil_Palm	70	30	90	100	100
27	**Olive**	**70**	**50**	**90**	**100**	**100**
28	Cotton	70	30	90	100	100
29	Flax	70	50	90	100	100
30	Sugarcane	70	30	90	100	100
31	Sugar_Beet	70	30	90	100	100
32	Banana_Plantain	70	30	90	100	100
33	Citrus	70	30	70	100	100
34a	Arabica_Coffee	70	30	70	100	100

Figure 5. Informatio flow for the model IV section regarding the Agro-edaphic suitability inside the GAEZ methodology (after IIASA/FAO, 2012)



Following this kind of quantitative "rating" translation of the suitability classes approach, it was prepared a proposal of matching table for land evaluation of the suitability to olive tree cultivation that could be a good framework to be applied at regional level. This table, carried out for perennial crop cultivations in a Mediterranean environment, could be easily adapted to the olive suitability in Pakistan by tuning in the right way the class limits of the climatic, topographic and soil parameters suggested. Some critical climatic parameter to take in account and introduce for Pakistan landscapes are the heat availability and chilling units, because in local conditions are crucial for planning a feasible olive tree cultivation.

Table 6.Critical climatic parameter for Olive cultivation in Pakistan

CLASSES	S1	S2	S3	N1	N2
Rating	**100-85**	**85-65**	**65-45**	**45-25**	**25-0**
Climate (c)					
Annual Precipitation mm (*)	>800	700 - 800	500 - 700	300 - 500	<300
Maximum value of the average monthly Temperature	18 - 20	20-25	25-27	27-29	>29

Minimum value of the average monthly Temperature	15-18	12-15	5-12	0-5	<0
Topography and soil surface (t)					
Slope %	<5	5-10	10-15	15-25	>25
Elevation m asl	0 - 500	500 - 700	700 - 1000	>1000	>1000
Aspect	Pianeggiante SE-SO	S – NE - E	SO - O	N - NO	N
Surface stoniness (%)	<1	1-3	3 -15	15 - 35	>35
Surface rock outcrops (%)	<2	2-5	5-10	10-50	>50
Soil (s)					
Internal Drainage	Well drained	Moderately well drained / Somewhat poorly drained	Somewhat excessively drained / Poorly drained	Excessively drained / Very poorly drained	Without drainage/ Excessively drained
Soil depth explorable by roots (cm)	>100	70-100	50-70	50 - 35	<35
Texture (USDA Class)	F, FSA, FL	FA, FS, L, AS	FLA, AL,	A < 60%, SF	S, A > 60% Coarse sand
Stoniness/gravel content (%)	<5	5-10	10-25	25–35	>35
Permeability (mm/h)	Moderately High 1 – 10 um/s	Moderately Low 0.1 – 1 um/s	Low 0.01 – 0.1 um/s High 10 – 100 um/s	Very Low < 0.01 um/s Very High >100 um/s	Very Low < 0.01 um/s Very High >100 um/s
Erosion risk	no	low	medium	high	Very high
Avaliable Water Capacity (mm)	>200	150 - 200	100 - 150	50 - 100	<50
Groundwater table depth (cm from the surface)	>100	80-100	100-50	25 - 50	<25
Soil fertility (f)					
Reaction (pH)	6,5-7,5	5.0–6.5 7.5-8.0	4.5 – 5.0 8.0 – 8.5	<4.5 8.5-9.0	<4.5 >9.0
Salinity dS/m	< 2	2 - 4	4 - 8	8 - 12 ESP 8 – 15%	> 12 ESP > 15%
Sodicity (ESP%)	<8	8-10	10-15	>15	>15
Organic Carbon %	>3.0	1.5 - 3.0	1.5 – 0.5	0.5 – 0.2	<0.2
Cation Exchange Capacity (meq/100gr)	>18	12-18	10-12	5 - 10	<5
Total Calcium Carbonates %	<8%	8-15%	15-25%	25-35%	>35%
Active Carbonates %	<2.5%	2.5-5%	5-8%	>8%	>8%

Conclusion

Based on the tools and techniques of the new GIS-based system that has been evaluated and described, it is possible to build a model to manage the evaluation of the land suitable for the cultivation of olive trees. The quality of information to be collected through surveys, or by remote sensing or data mining activities in the various institutions

present and operating in Pakistan, has a fundamental impurtance in order to make possible a reliable assessment of the characteristics and quality of the area. Based on the preliminary land assessment it will be possible to schedule the successful expansion of the olive crops. Semi-automatic models GIS-based applications can be very powerful tools if supported by a land database with quality and "high density" spatial information. With these tools it could be possible to: a) manage and reduce the uncertainty of the predictions valuation; b) handle different scenarios by changing one or more land / soil qualities in a dynamic way.

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In vitro screening of olive *(Olea europaea* L.*)* varieties for drought tolerance

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Abstract

Olive (*Olea europaea* L.) is one the most important edible oil crops in Mediterranean region and can be grown semi arid region. It provides edible oil to the millions of people for its unique nutritional and health regimes. Breeding for drought prone environments is constrained by lack of suitable selection indices of drought resistance and long juvenility span. The present work was conducted to determine the effect of *in vitro* drought stress on six important olive varieties by using PEG 6000 as osmoticum which created osmotic potential of -4, -6, -8 and -10 bars. The morphological and physiological responses of six olive varieties were analyzed, with complete randomized design. The results showed that drought stress severely affected all the varieties as the stress levels were increased. All genotypes recorded significant differences in most of traits in response to various moisture stress conditions. Fresh weight, dry weight, relative water contents, membrane stability index and potassium contents showed reduction with increasing levels of water stress differently in all six varieties while drought injury index was found to be elevated as the stress treatments were increased differently in all six varieties. The order of olive varieties according to drought tolerance is as Coratina, Dolce Agogia, Moraiolo, PS-1, VP-1 and Chetinea, based on the parameters considered.

Key words: Olive; *Olea europaea* L; *in vitro*; water stress; PEG 6000; morphophysiological characteristics

Introduction

Olive is one of the drought tolerant plant species and many studies have investigated its morphological and physiological adaptation to water stress. Olive cultivation is concentrated in the Mediterranean basin and its surroundings. Olive trees were cultivated in Pakistan since from many decades while wild olive was found in many districts of Punjab, KPK and Baluchistan. From the almost 3.3 million tones of olive oils estimated by IOOC was produced in the world during 2011/2012 crop year, 97% come from the Mediterranean region. For table olives, the other important olive product, 83% of the 2.6 million tons produced in the same year contributed from the same region.Pakistan is facing severe shortage of edible oil because our total production is only 30% of our entire need and remaining is imported from the other countries by spending over Rs. 44.21 billion every year (GOP. 2008). Nowadays olive is favorable choice for cultivation in arid areas due to its high stress tolerance. Drought stress is one of the most important environmental stresses affecting agricultural productivity around the world and may result in considerable yield reductions (Gaspar *et al*., 2002). It is the main problem being faced the olive growers. Olive is mostly grown in arid and semi arid areas, where plants frequently subjected to water stress, which results reduction in yield. Lack of irrigation water can impair the performance of its growth and production. A large number of molecular, biochemical and physiological processes at the cellular or whole plant level are altered in response to drought (Kaya *et al*., 2006) and play an important role in mitigating stress at the whole plant level the effect of stress is usually perceived as a decrease in photosynthesis and growth, and is associated with alteration in carbon and nitrogen metabolism (Wu and Cosgrove. 2000). This study aims at to investigate the response of six olive varieties grown in vitro stress condition on morphological and physiological responses to drought tolerance.

Materials and methods

To study the effect of *in vitro* stress, already established explants of six olive varieties (Coratina, Moraiolo, Dolce Agogia, Chetinea, VP-1 and PS-1) were cultured on the olive medium (Rugini, 1984) containing PEG 6000 at different levels. The shoot tips explants of targeted olive varieties were inoculated to the medium supplemented with different PEG (6000) concentrations which creating the osmotic potentials of -4.06 (T0), -5.95 (T1), -8.08 (T2) and -10.05 (T3) bars. The pH of the media was adjusted at 5.8 and autoclaved at 121°C for 16 minutes. The cultured explants were then incubated at 25 ± 1°C for 16 hours photoperiod. Following 6 weeks of incubation, the plants were washed by using distilled water until agar was completely removed and they were used for evaluating physiological and morphological responses.

Relative water content

The expanded leaves of the samples were collected and fresh weight (FW) was immediately measured and after it turgid weights (TW) of the samples were measured after dipping them in distilled water for a period of 4 hours

at room temperature while keeping the light constant. After drying the leaves for 36 hour at 70 °C, the dry weight (DW) of them were measured and then relative water contents (RWC) were calculated by using this formula (Weatherley and Barrs, 1962).

$$\textbf{RWC (\%) = [(FW - DW) / (TW - DW)] x 100}$$

Leaf membrane stability index (MSI)

Leaf membrane stability index (MSI) was measured by using the procedure of Chandrasekar *et al*. (2000). Leaf strips of 0.2g having equal size were made and put them in two sets of test tubes, added 10 ml of double distilled water in them. One set of them were incubated at 40 ^{o}C for 30 min and the second set were boiled at 100 ^{o}C in water bath for 15 minutes. The electrical conductivity of the both samples was measured (C1 and C2 respectively). MSI was calculated by using the formula of Chandrasekar *et al*. (2000).

$$MSI = [1- (C1/C2)] \times 100$$

Potassium contents

The plant samples were collected and after drying they were ground well. Took 1 g of dried grounded samples in test tube and added 1 N HCl to rinse the samples. 25ml of 1N HCl were added in test tube and kept it for 24 hours and then it was filtered with filter paper (Whatman No.1). The filtrates of the samples were used for the assessment of potassium contents by using flame photometer at potassium standards of 0, 20, 40, 60, 80, and 100 ppm (Yoshida *et al*., 1972).

Visual Scoring: The symptoms of injury caused by drought stress, were scored according to Sirvitipe *et al.* (2008) on a scale having numbering as 1 for without injury, 2 for browning of leaf edges and shoot-tips, 3 for whole leaf necroses or on any part of the shoots and 4 for fully dead plants. After this, the calculation of drought injury index (DI) was done by using formula;

$$DI = (ni \times I) / N$$

Where (ni) is the number of explants getting mark "I" (1 to 4) and the total number of explants in each treatment were represented by "N".

Statistical analysis

In the experiment there were two factors i.e. treatments and varieties, so that the experiment was arranged in a completely randomized design (CRD) having three replications of each treatment. The information were analyzed by using analysis of variance (ANOVA) as a statistical tool and variations in the means of treatments and varieties were looked at by using least significance difference (LSD) test with the 5% probability level (Steel *et al*., 1997).

Results

Fresh Weight (FW): Results in Table 1 reveal that increasing levels of drought stress in the culture media interacted significantly with all targeted olive varieties at $p< 0.05$ in terms of fresh weight. The effects of unstressed media with Coratina produced maximum fresh weight of 750.87 mg, while with increasing stress levels from -6 bars to -10 bars; a significantly reducing effect has been observed, as Chetinea and VP-1 showing the least values of 131.85 and 134.68 mg respectively at T_3 (-10 bars), however at the same level, Moraiolo and PS-1 showed 138.45 and 137.01 mg fresh weight respectively but Coratina and D-ago performed very well with the fresh weight of 141.50 141.73 mg.

Dry Weight (DW): Statistical analysis depicts a significant interaction of drought stress levels and olive varieties at $p < 0.05$ in terms of plant dry weight (Table 2). A significant reduction in the dry weight of all olive varieties as a result of drought stress has been recorded. Coratina interacted most superiorly with control and -6 bars stress level by attaining dry weight of 188.23 mg and 78.73 mg respectively. On the other hand, the worst results for dry weight (49.38 mg) were given by D-ago at -8 bars of stress (T_2).

Relative Water Contents (RWC %): Analysis of variance for RWC showed a significant effect of increasing levels of drought stress by the inclusion of PEG 6000 in the culture media on olive varieties at $p< 0.05$ (Table 3). A decrease in RWC was observed to be connected with the higher levels of PEG. The more awful cooperation has been indicated by Chetinea against -10 bars by decreasing water contents to 85.73 % while; Coratina retained maximum water contents 89.36% under control which were significantly higher than all other interactions.

Leaf Membrane Stability Index (MSI): Effect of water stress treatments on olive varieties show significant statistical variations at $p < 0.05$ in terms of leaf membrane stability indices as shown in Table 4. The best interaction has been revealed by Moraiolo, Coratina and D-ago giving MSI values of 55.08, 54.88 and 54.37 respectively at control (T_0). The increase in water stress caused significant decrease in membrane stability index in all varieties where as the Chetinea and VP-1 demonstrating the lowest interactions at -10 bars with MSI values of 33.27 and 3302.

Potassium contents (mg g^{-1} DW): In the olive varieties the potassium contents were significantly affected with the increase in severity of water stress. The best interaction of treatment and varieties at $p > 0.05$ has been shown by Moraiolo, Coratina and D-ago attaining K contents of 4.79, 4.73 and 4.57 mg g^{-1} at controlled treatment (T_0). As increasing the water stress, a significant decrease is observed in the potassium contents of all olive varieties, while VP-1 and Chetinea revealed the lowest potassium contents of 2.56 and 2.52 mg g^{-1} respectively against T_3 (-10 bars) of stress as represented in Table 5.

Visual Scoring (DI): The presentation of data (Table 6) demonstrates a significant interaction between water stress and the drought injury index of the all six olive varieties at $p < 0.05$. Chetinea exhibited the most elevated value of drought injury (2.907) at osmotic stress level of -10 bars (T_3) in contrast to T_0 where all the varieties performed well. The most superior interaction shared by all the olive varieties at zero stress level (T_0).

Table 1: Effect of different levels of *in vitro* drought stress on fresh weight (mg) of olive varieties.

Treatments (PEG 6000)	**Fresh weight (mg)**						**Mean**
	Coratina	**D-Ago**	**Moraiolo**	**PS-1**	**VP-1**	**Chetinea**	
T_0(Control)	750.87 a	717.76 a	701.92 bc	702.23 bc	695.53 c	695.46 c	710.63 a
T_1(-6 bars)	293.87 d	278.53 de	257.97 f	265.77 ef	259.55 f	259.13 f	269.14 b
T_2(-8 bars)	193.10 g	183.89 gh	180.00 gh	173.74 hi	161.63 i	160.06 i	175.40 c
T_3(-10 bars)	141.50 j	141.73 j	138.45 j	137.01 j	134.68 j	131.85 j	137.54 d
Mean	344.83 ab	330.48 ab	319.58 a	319.69 ab	312.85 b	311.62 b	

$LSD_{0.05}$ Variety (V) 9.161 Interaction (V×T) 18.322 Treatments (T) 7.480

There are not any two mean values which share a letter that is significantly different at p<0.05

Table 2: Effect of different levels of *in vitro* drought stress on dry weight (mg) of olive varieties.

Treatments (PEG 6000)	**Dry weight (mg)**						**Mean**
	Coratina	**D-Ago**	**Moraiolo**	**PS-1**	**VP-1**	**Chetinea**	
T_0(Control)	188.23 a	183.56 b	179.54 c	174.98 d	172.87 d	173.53 d	178.79 a
T_1(-6 bars)	78.73 e	76.63 ef	73.83 fg	74.05 fg	72.43 g	73.47 fg	74.86 b
T_2(-8 bars)	50.44 h	49.38 h	51.30 h	51.52 h	50.47 h	51.08 h	50.70 c
T_3(-10 bars)	43.67 i	43.66 i	41.72 ij	40.92 ij	41.29 ij	39.68 j	41.82
Mean	90.27 a	88.31 b	86.60 bc	85.37 cd	84.28 d	84.44 d	

$LSD_{0.05}$ Variety (V) 1.8590 Interaction (V×T) 3.7180 Treatments (T) 1.5178

There are not any two mean values which share a letter that is significantly different at p<0.05

Table 3: Effect of different levels of *in vitro* drought stress on Relative water contents (RWC %) of olives varieties.

Treatments (PEG 6000)	Relative Water Content (%)						Mean
	Coratina	**D-Ago**	**Moraiolo**	**PS-1**	**VP-1**	**Chetinea**	
T_0(Control)	89.363 a	88.413 bcd	88.570 b	88.480 bc	87.710 cdefgh	87.757 cdefgh	88.382 a
T_1(-6 bars)	88.237 bcde	87.947 bcdef	88.243 bcde	87.833 bcdefg	87.110 ghij	87.110 ghij	87.747 b
T_2(-8 bars)	87.433 fghi	87.663 defgh	87.497 efghi	87.090 ghij	86.413 jkl	86.230 kl	87.054 c
T_3(-10 bars)	86.713 ijk	87.017 hijk	86.990 hijk	86.813 ijk	86.497 jkl	85.727 l	86.626 d
Mean	87.937 a	87.937 a	87.825 a	87.554 a	86.932 b	86.706 b	

LSD $_{0.05}$ Variety (V) 0.3941 Interaction (V×T) 0.7883 Treatments (T) 0.3218

There are not any two mean values which share a letter that is significantly different at $p<0.05$

Table 4: Effect of different levels of *in vitro* drought stress on leaf membrane stability index (MSI) of olive varieties.

Treatments (PEG 6000)	Leaf Membrane Stability Index						Mean
	Coratina	**D-Ago**	**Moraiolo**	**PS-1**	**VP-1**	**Chetinea**	
T_0(Control)	54.887 a	54.367 b	55.087 a	51.420 c	50.413 d	48.547 e	52.453 a
T_1(-6 bars)	41.637 f	39.360 h	40.803 g	37.300 j	36.323 l	35.647 m	38.512 b
T_2(-8 bars)	38.747 i	37.617 j	37.460 j	35.280 n	34.717 o	33.843 p	36.277 c
T_3(-10 bars)	36.717 k	36.863 k	35.673 m	34.143 p	33.023 q	33.267 q	34.948 d
Mean	42.997 a	42.052 c	42.256 b	39.536 d	38.619 e	37.826 f	

LSD $_{0.05}$ Variety (V) 0.1746 Interaction (V×T) 0.3492 Treatments (T) 0.1426

There are not any two mean values which share a letter that is significantly different at $p<0.05$

Table 5: *In vitro* drought stress caused reduction in potassium contents (mg g^{-1}DW) of olive with increasing stress levels

Treatments (PEG 6000)	Potassium Content (mg/g)						Mean
	Coratina	**D-Ago**	**Moraiolo**	**PS-1**	**VP-1**	**Chetinea**	
T_0(Control)	4.73 a	4.57 ab	4.79 a	4.39 bc	4.11 de	3.94 ef	4.42 a
T_1(-6 bars)	4.69 a	4.37 bc	4.17 cde	4.05 de	3.54 gh	3.48 h	4.05 b
T_2(-8 bars)	4.21 cd	4.16 cde	3.74 fg	3.30 hi	3.20 i	3.18 i	3.63 c
T_3(-10 bars)	3.47 h	3.11 ij	3.13 i	2.88 j	2.55 k	2.52 k	2.94 d
Mean	4.27 a	4.05 b	3.95 b	3.65 c	3.35 d	3.28 d	

LSD $_{0.05}$ Variety (R) 0.1260 Interaction (R×T) 0.2519 Treatments (T) 0.1029

There are not any two mean values which share a letter that is significantly different at $p<0.05$

Table 6: Effect of different levels of *in vitro* drought stress on drought injury index (DI) of olive varieties.

Treatments (PEG 6000)	Drought Injury Index (DI)						Mean
	Coratina	D-Ago	Moraiolo	PS-1	VP-1	Chetinea	
T_0(Control)	1.00 i	1.00 i	1.00 i	1.00 i	1.00 i	1.00 i	1.00 d
T_1(-6 bars)	1.540 h	1.527 h	1.543 h	1.560 h	1.563 h	1.570 h	1.55 c
T_2(-8 bars)	2.263 g	2.373 f	2.350 fg	2.560 e	2.670 d	2.813 c	2.51 b
T_3(-10 bars)	2.803 c	2.980 a	2.880 bc	2.830 bc	2.873 bc	2.907 ab	2.88 a
Mean	1.902 d	1.970 c	1.943 cd	1.986 bc	2.027 b	2.073 a	
LSD $_{0.05}$	Variety (V) 0.0449		Interaction (V×T) 0.0898		Treatments (T) 0.0366		
There are not any two mean values which share a letter that is significantly different at $p<0.05$							

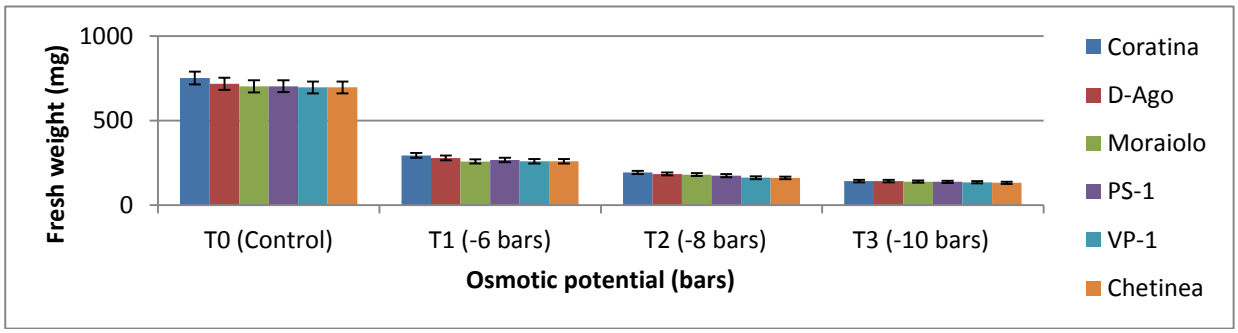

Figure 1. Effect of different levels of *in vitro* drought stress (x-axis) on fresh weight in mg (y-axis) of olive varieties at 5% level of significance.

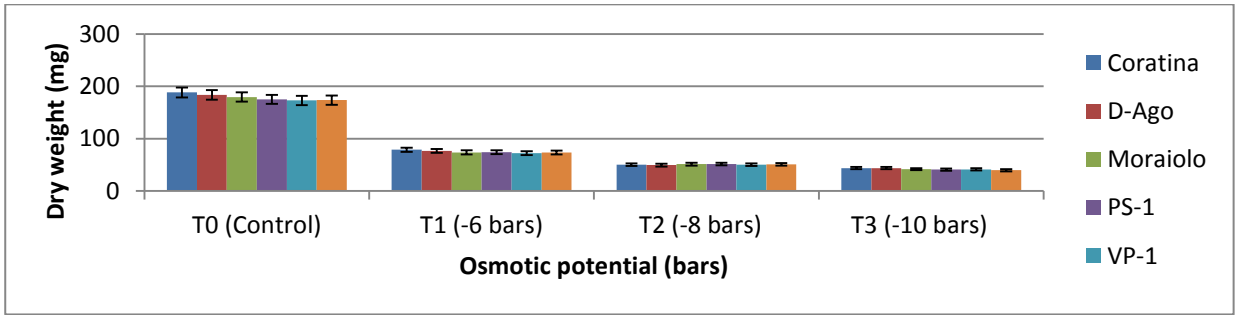

Figure 2. Effect of different levels of *in vitro* drought stress (x-axis) on dry weight in mg (y-axis) of olive varieties at 5% level of significance.

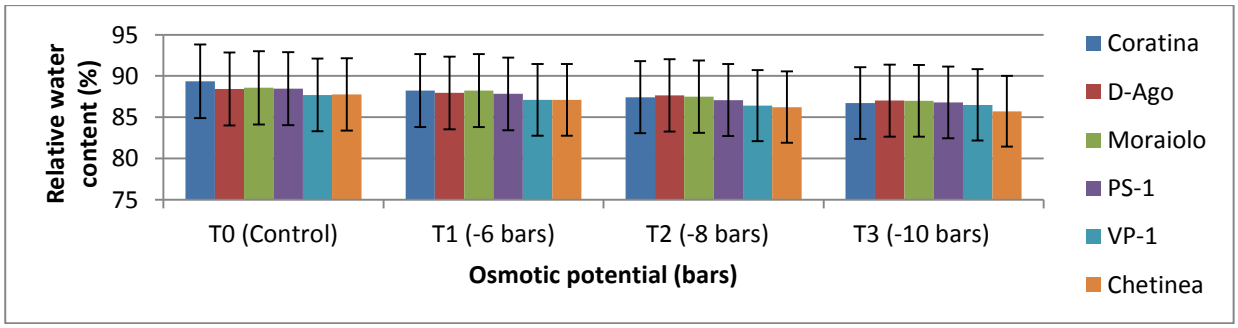

Figure 3. Effect of different levels of *in vitro* drought stress (along x-axis) on relative water content in % (along y-axis) of olive varieties at 5% level of significance.

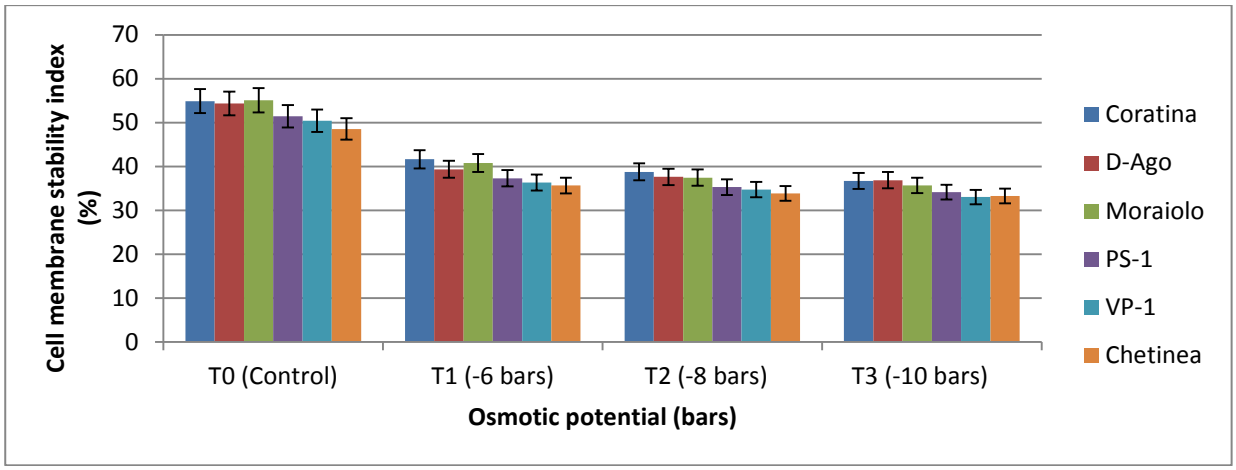

Figure 4. Effect of different levels of *in vitro* drought stress (along x-axis) on cell membrane stability index (along y-axis) of olive varieties at 5% level of significance.

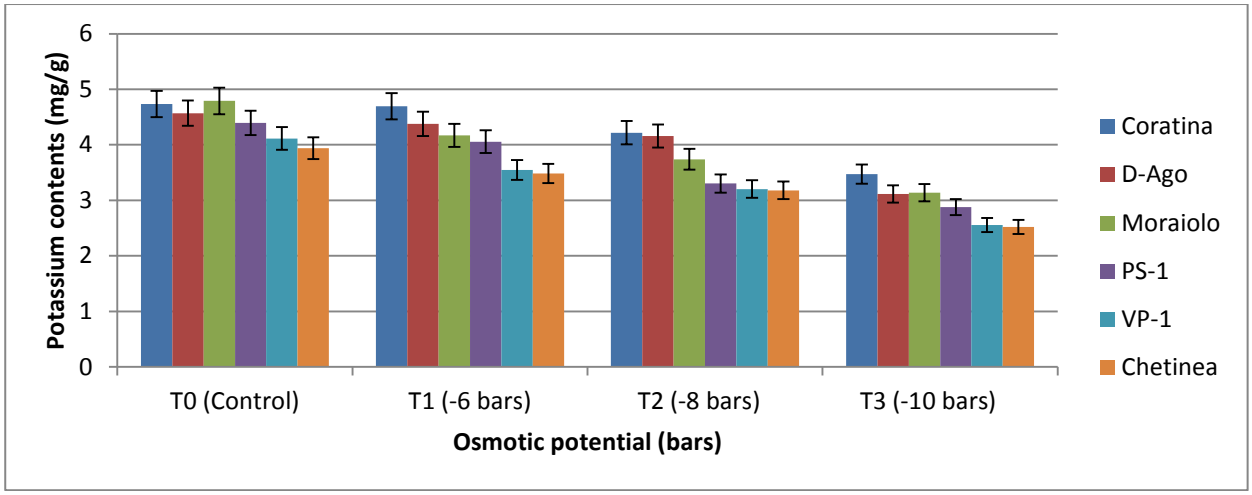

Figure 5. Effect of different levels of *in vitro* drought stress (along x-axis) on potassium contents in mg/g (along y-axis) of olive varieties at 5% level of significance.

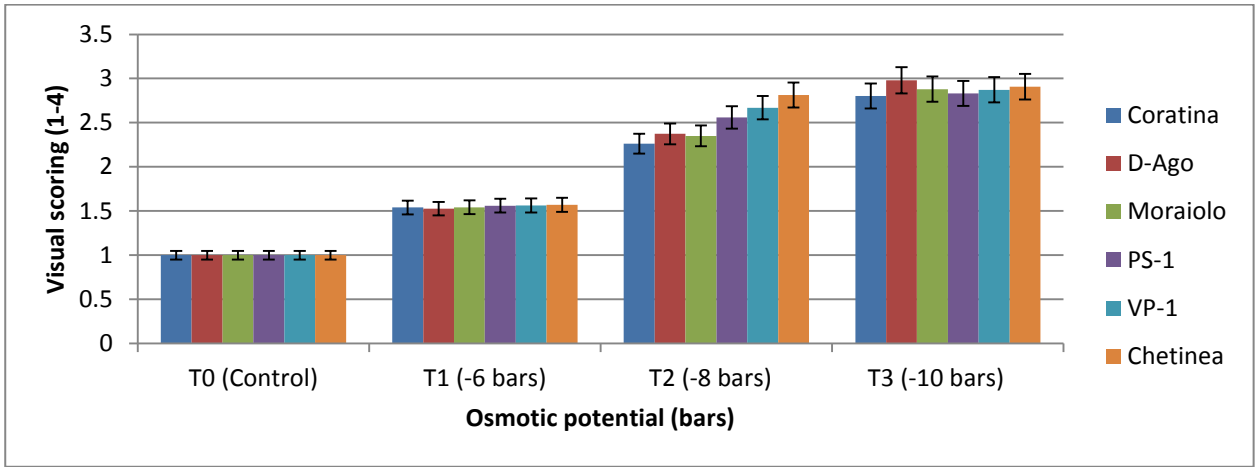

Figure 6. Effect of different levels of *in vitro* drought stress along x-axis on drought injury index (along y-axis) of olive varieties at 5% level of significance.

Discussion

Fresh Weight (FW): The addition of PEG to the olive medium decreased the water potential of the media inducing water stress that adversely affected the shoot growth of the olive cultivars (Fig. 1). Several authors reported the use of PEG for *in-vitro* drought screening in crop plants (Dragiiska *et al*., 1996; Gopal and Iwama, 2007). PEG-induced water deficit produced substantial dehydration that led decrease in fresh weight and reduced overall growth in all cultivars. The decrease in osmotic potential in root zone has considerable effect on the absorption of water by the roots and subsequently decrease the water content in the leaves and plant those have not well adopted mechanisms for drought tolerance cannot maintained their turgor in the leaves, hence wilting occur and reduced the growth (Bajji *et al*., 2000; Munns, 1988). The plants those have potential cellular mechanisms of drought resistance as they enables the turgor maintenance, showed the more fresh weight as in Coratina and D-ago, as compared to VP-1 and Chetinea which showed lower fresh weight due to their lesser adoptability to cope the drought conditions. The adopted mechanisms are closing of stomata that conserve water and accumulation of osmolytes in cell vacuoles that helps in water absorption against the potential gradient and reduce water losses in dry environment (Bajji *et al*., 2000). The presence of PEG in the growth medium had a detrimental effect upon most parameters associated with plantlets growth and fresh weight. There was a gradual decrease in the size and area of leaves as the PEG concentration increased, in all olive cultivars. A similar decrease in plantlet growth under *in-vitro* stress conditions was reported in potato (Gopal and Iwama, 2007) and rice (Binh *et al*., 1992).

Dry Weight (DW): The dry matter is decreased significantly in olive cultivars as the stress level increased (Fig. 2). Okcu *et al.* (2005) reported the decrease in dry weight of pea seedlings by increasing the concentration of PEG in the growth medium.The plants pay their metabolic cost in the form of reduced growth in water deficit conditions. The olive cultivars that have the ability to accumulate osmolytes, such as Na^+, Cl^- and K^+ etc. and other biomolecules such as proline, polyalcohols, sugars etc. to cope drought stress have more dry weight, so the more dry weight is a desired character for drought tolerance. The olive cultivar D-ago showed the minimum dry matter which showed lesser degree of drought tolerance with respect to dry matter where as the Coratina showed maximum dry matter as compare to all other cultivars under study which is good indication of its drought tolerance. The decrease in the dry matter production of the stressed plants could be justified by the fact that it is related with the process of dry matter partitioning and allocation. Photosynthetic capacity is the prime component of dry matter production in plants affecting plant growth, development and yield which vary with the change in the ecological factors (Natr and Lawlor, 2005). Disturbance in the supply pool such as nutrient and water may affect the allocation of dry matter (Soriano *et al.*, 2004).

Relative Water Contents (RWC %): Relative water content is one of the essential and generally utilized strategies to survey plants responses against water stress. It is additionally accepted to be a key marker of drought stress in leaves that is identified as directly affect the other leaf physiological mechanism for example process photosynthesis, turgidity, evapotranspiration, and closure of stomata, this impacts the capacity of the plant to recoup from anxiety and subsequently influences the production and yield steadiness (Kramer and Boyer, 1995). A decrease in relative water contents was observed (Fig. 3) to be connected with the higher levels of PEG. The more awful cooperation has been indicated by Chetinea against-10 bars by decreasing water contents while; Coratina retained maximum water contents under control and stressful conditions which were significantly higher than all other interactions. The more water contents in Coratina are due to its greater adoptability to absorb water from medium of higher concentration of PEG and accumulation of potassium ions in the cell vacuoles. The retention of water in the cells is might be due decrease in leaf area and reduced internodes distance as shown in the plate 1.

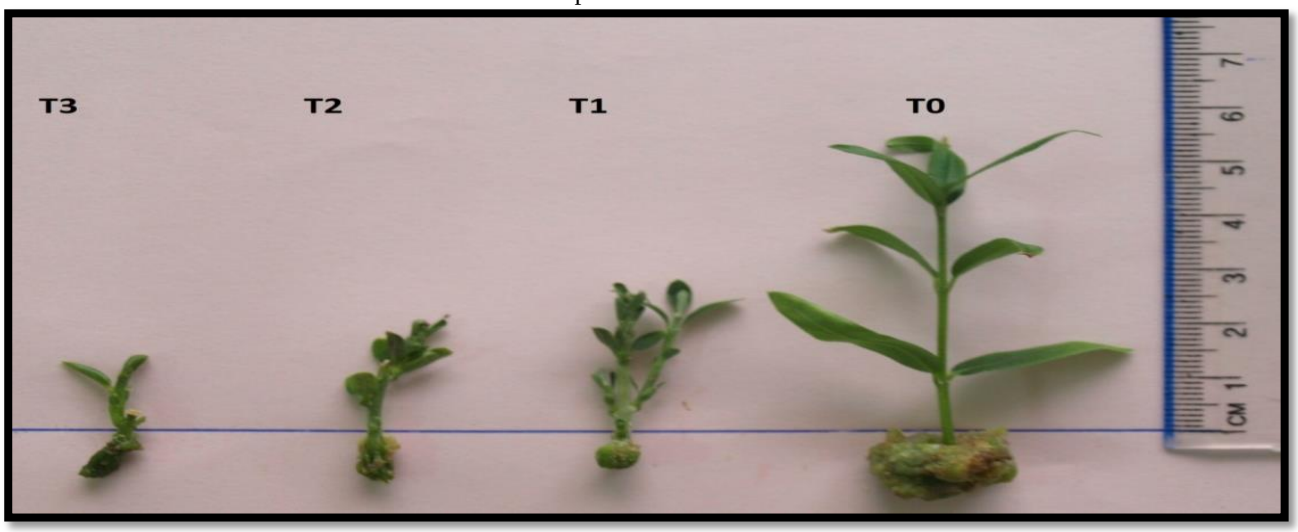

Plate 1. Effect of drought stress on olive plants (c.v Coratina) on growth, leaf area, leaf thickness and internodal distance.

Leaf Membrane Stability Index (MSI): Protection of the cell membrane stability under drought condition is one of the basic mechanisms for the tolerance of water shortage in plants (Bajji *et al.*, 2001). In water stressful conditions the mechanical structure of the vacuolar membrane is loosened in this way discharging the vacuolar substance, creating blasting of the chloroplasts on contact. This interruption in cell compartmentalization causes release of hydrolases, for example lipases that reason annihilation of layers(Chai *et al*., 2005). Along this the membrane injury is attributed to oxidative stress, as a secondary damage of water stress(Khan *et al*., 2009). The leakage of electrolyte from the membrane has used for the measurement of the degree of membrane injury resulted from the desiccation or rehydration event, in this way permitting the assessment of the capacity to keep up the uprightness of the membrane at low water potential (Franca *et al*., 2000). In the present study the best interaction has been revealed by Moraiolo, Coratina and D-ago giving more membrane stability at controlled conditions as compare to remaining cultivars which show the earlier cultivars are more tolerant to later cultivars (Fig. 4). The degree of tolerance with increased in water stress decreases in membrane stability index; Chetinea and VP-1 demonstrating the lowest interactions at -10 bars whereas the Coratina, Moraiolo and D-ago showed better tolerance at the same level of stress.

Potassium contents (mg g^{-1} DW): The amount of potassium contents in plants is a key marker of their degree of water stress tolerance and it reflects the straightforwardness at which plants can extricate moisture from the media when there is less accessibility of water (El-Hadi *et al.*, 1997). In the olive varieties the potassium contents were significantly affected with the increase in severity of water stress (Fig. 5). The best amount of potassium contents has been shown by Moraiolo, Coratina and D-ago attaining K contents at controlled treatment. As increasing the water stress, a significant decrease is observed in the potassium contents of all olive varieties, while VP-1 and Chetinea revealed the lowest potassium contents against T_3 (-10 bars) of stress. This diminishing pattern in K status of the water stress targeted plants could be because of its negative impact on the diffusion of K into the plants or the limited amount of K in the nutrient media (Bartels and Sunkar, 2005). The decrease in K contents might be due to loss of membrane stability as the stress level increased (Chaves *et al*., 2003). Moreover, higher potassium level of plants in the spells water stress have a defensive part against the harms due to photo oxidation and in addition, it is also helps in the stomatal conductance keeping in view that to minimize the water deficiency by timely stomatal conductance (Egilla *et al.*, 2001).

Visual Scoring (DI):. Stress treatments with increasing concentration of PEG 6000 caused significant elevation in the drought injury scoring. Osmotic stress of -10 bars proved to be the severest where DI values. The symptoms appeared as dark-green, dry leaves, interveinal stains which turned yellow and then necrosis of leaves and shoot tips. Severely damaged leaves eventually died on the stem. This is due to decrease in the performance of cell machinery in stressful environment which causes closing of stomata, lowering CO_2 penetration in the leaves and reduced photosynthetic rate, loss in membrane stability and active absorption of nutrients against potential gradients causes the more consumption rate of photo assimilates then their production rate which causes the necrosis (Ashraf *et al*., 2005). Similar results have been also found in the cherry evaluated for drought tolerance *in vitro* showing degradation of chlorophyll with the increase in stress and accumulation of proline in the leaf tissues (Sivritepe *et al.*, 2008).

Conclusion

In recent years, considerable progress has been made regarding the screening of crop plants against abiotech stress mainly drought and salt tolerant genotypes. *In vitro* selection will save the time required for developing disease resistant and abiotic stress tolerant genotypes of important plant species. The present research provides help to determine the degree of drought stress on six important olive varieties. The morphological and physiological responses of six olive varieties provide the information about the adaptation taken by all cultivars under study in stressful environment. The results showed that drought stress severely affected all the varieties as the stress levels were increased. All genotypes recorded significant differences in most of traits in response to various moisture stress conditions. Fresh weight, dry weight, relative water contents, membrane stability index and potassium contents showed reduction with increasing levels of water stress differently in all six varieties while drought injury index was found to be elevated as the stress treatments were increased differently in all six varieties. The order of olive varieties according to drought tolerance is as Coratina, Dolce Agogia, Moraiolo, PS-1, VP-1 and Chetinea, based on the parameters considered. In vitro selected variants should be finally field-tested to confirm the genetic stability of the selected trait (Jain, 2001). *In vitro* selection incorporated with molecular and functional genomics can provide a new opportunity to improve stress tolerance in plants relevant to food production and environmental sustainability.

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Synthetic seed: A potential tool for exchange of olive germplasm

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Abstract

Synthetic seed technology is an important tool for propagation of those plants mostly which are asexually propagated. It has open influential advantages for large scale propagation of important plant species. Synthetic seeds of five Olive (*Olea europaea*) varieties Moraiolo, Chitinia, PSI, VPI and D. Agogia were prepared from first four nodes of *in vitro* proliferated shoots, by excising 3-4 mm uni-nodal micro cuttings (MCTS) without leaves. The MCTS were inserted into culture medium containing root induction medium (RIM). The MCTS with root primordia were taken out and used for encapsulation with sodium alginate. The prepared synthetic seed were stored at 4 °C for one week in Biotech Lab University of Perugia, Italy. The bottles of synthetic seed in a carton were sent through DHC Corrier Service at ambient temperature condition within 4 days to Biotech Lab PMAS-AAUR Pakistan. These synthetic seed after one week stored at 4 °C were cultured successfully and proliferated shoots were subcultured several times and planlets were prepared after root induction. After acclimatization plants were shifted to lath house and after 2 year plants were planted in the field at University Research Farm Koont. Plants are healthy and are at bearing stage. This technology can be a good substitute to conventional seeds.

Key words: Alginate encapsulation; micro-cuttings; artificial seed; synthetic seed storage

Introduction

Synthetic seed technology is an important tool for propagation of those plants mostly which are asexually propagated. It has open influential advantages for large scale propagation of important plant species. This technology is a good substitute to conventional seeds. The synthetic seeds are defined as the synthetically encapsulation of somatic embryos or any other meristematic tissue which may be axillary buds or shoot tips, used as a seeds and have the ability to convert into whole plant under controlled conditions and maintain its potential to germinate/regrow after storage (Capuano *et al*., 1998). The somatic embryo can be encapsulated, handled and used like a natural seed was first suggested by Murashige (1977) and efforts to engineer them into synthetic seed have been ongoing ever since Kitto and Janick (1982), Gray (1987). It helps in the establishment of germplasm repositories of traditionally micropropagated plants for further study is now difficult, due to limited space and requirement of huge amount of money for their maintenance. An implementation of artificial seed technology to the regeneration of embryos or somatic embryogenesis is based on the meristematic tissues as an efficient technique that allows for mass propagation in a large scale production of a selected genotype (Ara *et al*., 2000). The aim and scope for switching towards artificial seed technology was for the fact that the cost-effective mass propagation of elite plant genotypes will be promoted. It is also a way for new transgenic plants which are biotechnologically produced to be transferred directly to the greenhouse conditions or in the field. The artificial seed technology has been applied to a large number of plant species of angiosperms. Present review aimed to give a brief description of methodology involved in synseed preparation in Olive (*Olea europaea* L.) belonging to family Oleaceae, storage of synthetic seeds, exchange of germplasm, germination and plant development. The exchange of stock cultures between laboratories is also problematic in consideration with temperature fluctuations and danger of infestation with microorganisms. Synthetic seeds provide an alternative dependable way for mass scale production, efficient delivery of cloned plantlets and also to meet the international quarantine requirements. Exchange of plant germplasm between the different laboratories and successfully regeneration of the plants from the synthetic seeds has been reported earlier in several plants (Fabre and Dereuddre, 1990; Maruyama *et al*., 1997).

Synthetic seeds preparation

Explants used for Synthetic Seed Preparation

Ever since synthetic seed technique was developed, the somatic embryos are mostly used because of their ability to produce plumule and radical (Kitto and Janick, 1982, 1985 a, b; Kim and Janick, 1987, 1989, 1990; Janick *et al*., 1989; Redenbaugh *et al*., 1984; Redenbaugh *et al*., 1991b; Gray *et al*., 1991; Redenbaugh, 1993; McKersie and Bowley, 1993). Later on vegetative propagules e.g. shoot tips in *M. indica* (Bapat *et al*., 1987), axillary buds in *Camellia sinensis* (Mondel *et al*., 2002), calli in *Allium sativum* (Kim and Park, 2002), bulblets in *A. sativum* (Bekheet, 2006), cell aggregates derived from Horse-radish hairy roots (Repunte *et al*., 1995) and protocorm like bodies in *Geodorum densiflorum* (Datta *et al*., 1999) were also used. In addition to the other *in vitro* derived meristematic tissues

like microtubers, rhizomes and corms can also been used (Bapat and Minal, 2005). In olive plants, the microcuttings are prepared from *in vitro* proliferated shoot are excised to prepare uninodal segments of 3-4 mm in length for encapsulation.

Induction of somatic embryogenesis

One necessity for the use of artificial seed technology is the production of good quality somatic embryos. Initiation of somatic embryogenesis there must required changes in the somatic cells. They required inductive treatments to stimulate the division cells and then set up a polarity in these somatic cells. It is conducted in many cases by plant hormones, among these auxins are essential for the initiation of embryogenesis in somatic cells. The indole-butyric acid (IBA) and 2,4-dichlorophenoxyacetic acid (2,4-D) are the auxins which are most commonly used in many plant species. The somatic cells which are forced for embryogenesis are unique, they are similar to meristematic cells, generally smaller, their shape is more isodiametric, have a denser cytoplasm and also have more densely staining and larger nuclei and nucleoli (Williams and Maheswaran, 1986; Carman, 1990). After the completion of embryogenesis, the processes are like the formation of zygotic embryo as passing through different stages of globular shape, heart-shape and then torpedo-shape. These processes can be improved with induction of osmotic stress, changing in nutrients medium and reduction in humidity etc.Somatic embryogenesis is the only clonal propagation system economically viable. However somatic embryos would require mechanical strength for planting and it would be advantageous to change them into encapsulated units.

Encacapsulating agents and endosperm composition

Eight different chemical compounds were tested for the preparation of artificial seed coats, 'Polyox', the most appropriate chemical agent for the somatic embryos encapsulation is water soluble resin (Kitto and Janick 1982, 1985c). However, Redenbaugh *et al*. (1984, 1986 and 1987) descrobed that the most suitable agent for the encapsulation is sodium alginate in few species such as alfalfa, cauliflower, celery and carrot. It is the most used hydro-gel for synthetic seeds, due to its low cost, low toxicity and biologically compatible nature (Saiprasad, 2001). In olive the encapsulation is done with sodium alginate (Sigma code A-2033) 2.5 % (w/v) solution, enriched with artificial endosperm which is composed of half strength OMM (Olive Modified Medium) with addition of 1 mg l^{-1} zeatin and 20 g l^{-1} sucrose + 10 g l^{-1} glucose.

Encapsulation procedure

The most appropriate method for the preparation of synthetic seeds was the hydro-gel encapsulation method developed by Redenbaugh *et al*. (1987). According to this method, sodium alginate is prepared by mixing with calcium free liquid Olive Medium and then the explants are mixed with the solution. Explants are sucked with a pipette along with the solution of sodium alginate and dropped into 1.1 % (w/v) solution of the calcium chloride $CaCl_2$ and then endosperm solution for 35 minutes, where the ion exchange reaction take place and calcium ions replaced sodium ions and form the beads of calcium alginate. After the complexation take place, beads are washed twice for 15 minutes with autoclaved rinse solution which is consist of artificial endosperm only. The whole process must be done under aseptic conditions. The capsule size depends on the diameter of the pipette nozzle. The shape and texture of the beads depends on the calcium chloride and sodium alginate concentration and complexion period. Molle *et al*. (1993) describes the use of a nozzle pipette of two different sizes of inner and outer pipette in which the alginate solution passes through the outer pipette and the embryos flow through the inner pipette, due to which the embryos are remained in the center of capsule for better protection.

Preparation of olive Synthetic Seed

In preparation of synthetic seeds of olive plants, the plants are culture in in vitro conditions by using OMM (Olive Medium Modified, Mencuccini *et al*., 1997), with addition of 4 mg l^{-1} zeatin, 30 g l^{-1} sucrose and 6.5 g l^{-1} agar. Subculturing of single uninodal segments of about 10-15 mm length, with two opposite leaves having axillary buds, are done after every 45 days. After two subsequent subcultures, microcuttings are prepared from *in vitro* proliferated shoots. First four nodes of each proliferated shoot are excised to prepare uninodal segments of 3-4 mm in length, remove leaves and should have at least two lateral buds Fig 1. These microcuttings are inserted into culture jars containing root induction medium, comprising of half strength OMM with addition of 0.5 mg l^{-1} IBA, 10 g l^{-1} glucose + 20 g l^{-1} sucrose, 100 mg l^{-1} brilliant black dye and solidified with agar. After 11 days, microcuttings with root primordia are taken out from root induction medium used for encapsulation Fig 2.

Storage of olive synthetic seeds and germplasm exchange

Capsules are stored in glass bottles along with artificial endosperm solution so that it helps to maintain the relative humidity in the bottle during storage. Ikhlaq *et al*., (2010) reported a possibility of transfer of axenic plant material from Europe to Asia in the form of synthetic/ artificial seed and to evaluate the comparative regrowth and

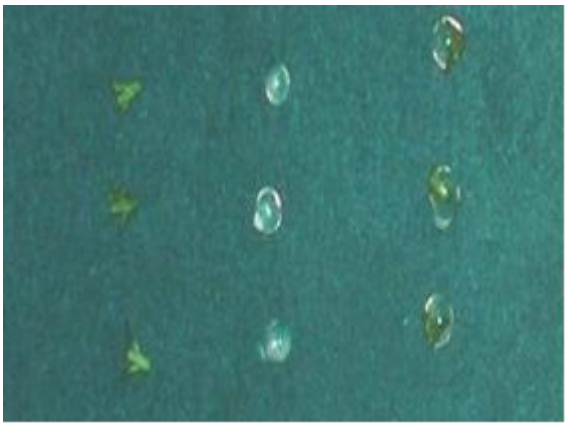

Figure 1. Micro-cuttings of 3-4 mm in size With alginate matrix

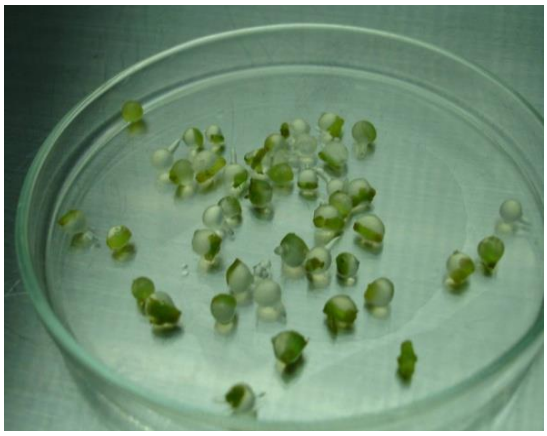

Figure 2. Micro-cuttings encapsulated with alginate

conversion capacity of synthetic seeds of olive cv. Moraiolo under cold (4 ^{0}C) and room storage (21 ± 2 ^{0}C) conditions in interaction with different storage intervals. The glass bottles of synthetic seed were packed in cartons and sent through DHL Courier Service, under ambient temperature conditions within four days to Biotech Lab. Arid Agriculture University Rawalpindi Pakistan. The synthetic seed was used after one week storage at 4 C to establish cultures that were maintained on OMM (Olive Medium Modified, Mencuccini *et al*., 1997), supplemented with 4 mg l^{-1} zeatin, 30 g l^{-1} sucrose and 6.5 g l^{-1} agar. Cold stored synthetic seeds are superior in terms of regrowth capacity than that of at room temperature stored. An elevated rate of rooting (35.0 %) was observed at cold storage after 45 days interval while at room temperature the maximum rooting (19.0 %) was recorded after 15 days interval. Furthermore, it has also been found by Grigoriadon *et al*. (2002) that polyamines increase the rooting percentage of olive.

Effect of storage conditions on *in vitro* germination and growth

The synthetic seeds have the opportunity of being an alternative plant material meant for agriculture sector in the future for the important plant species (Asmah *et al.*, 2011). Synthetic seeds can be used for direct planting into the greenhouse and fields, thus skipping many of the intermediate steps. Fujii *et al*., 1992 reported successful field planting of alfalfa synthetic seeds encapsulated in calcium alginate with 23% plant conversion. Earlier experiments on encapsulation of somatic embryos through calcium-sodium alginate from anther culture are performed in order to determine the effect of on the regeneration and the application of the synthetic seed techneques to *Citrus reticulata* (Antonietta *et al*., 2007). In olive plant the germination of synthetic seeds is also effected by storage conditions as described by Ikhlaq *et al*., (2010), and also they measured the germination % which shows the effect of different storage temperatures (4 ^{0}C & 21 ± 2 ^{0}C) of stored synthetic seeds. Cold storage (4 ^{0}C) gave the highest rate of regrowth (77 %) which was significantly different from that, yielded by room storage (21 ± 2 ^{0}C) i.e. 66.5 %. Cold storage might be responsible to slow down the metabolic activities of the synthetic seeds and maintain them in a visual quiescent state that is desired during storage. Cold storage has been reported as another method used for the preservation of a variety of plant species grown *in vitro* (Janeiro *et al*., 1997). The numbers of shoots per synthetic seed were almost similar in response to cold (1.56) and room (1.55) storage although statistically different which revealed that both the storage conditions were not highly different from each other in terms of shoot number per synthetic seed. This might be due to the morphology of encapsulated microcuttings that bear two opposite axillary buds each of which produced a shoot regardless of the storage temperature. Micheli *et al*. (2007) reported that the nodal microcuttings contain two opposite buds and they usually produce two shoots in each nodal cutting. Furthermore, the phenomenon of apical dominance might be suppressed by cutting the shoots into individual nodal segments for the purpose of microcuttings preparation, but; under normal subculturing conditions, a single olive shoot shows always apical dominance/ suppressing effects on the tiny/ rudimentary shoot from the second axillary bud on the same node of *in vitro* maintained shoots (Micheli *et al*., 2007). Shoot length of plantlets of olive synthetic seeds pursued the higher score for shoot length (1.57 cm) was observed at cold storage relative to the synthetic seeds stored at room storage, which produced 1.09 cm shoot length. It was observed that both the storage conditions (cold & room) did not cease the growth and developed shoots were healthy, green and free from any morphological disorder. Withers (1991) reported that slow growth *in vitro* may be obtained by low temperature and it increases the maximum storage duration. Furthermore the comparison of the two different storage conditions on rooting percentage proved the cold storage to be superior with an acquisition of 28.20 % rooting rate; whereas, at room storage merely 13.60 % rooting was observed. Higher rooting percentage after cold storage might be due to accumulation of carbohydrates in root primordial as Ahmad *et al*. (2007) stated that root initiation is an energy requiring process and continuous supply of carbohydrates is necessary for normal root development. Moreover, the internal carbohydrate pool is reported to have an important role in morphogenesis of several woody species (Kromer and Gamian, 2000; Li and Leung, 2000).

Green house and field planting

The plantlets are acclimatized in green house condition and hardening can be achieved by a simple procedure already proposed by Roussos and Pontikis (2002) that simplified the acclimatization process. Ikhlaq *et al*., (2010) transferred the plantlets directly to pots containing soil and sand (1:1), and placed in glass house having light intensity of 4000 –10,000 lux and relative humidity of 90-95 % with a temperature ranging from 26-28 ^{0}C. Synthetic seeds stored under cold storage conditions were better acclimatized and gave maximum survival percentage (28.4 %) as compare to those stored at room storage (17.4 %). Furthermore, plants regenerated from cold stored synthetic seeds resulted in a higher shoot length during acclimatization than those regenerated from room stored one Fig4. This depicts that cold storage positively increased the success rate during hardening or acclimatization of olive cv. Moraiolo. The plantlets produced from synseeds; with 4-6 fully expanded leaves and well developed roots Fig 3. These plantlets are successfully acclimatized under greenhouseconditions. This protocol can also be used successfully for preparation of synthetic seed exchange of germplasm of woody trees. After acclimatization plants of five olive Cv. Moraiolo, Chitinia, PSI, VPI and D. Agogia were shifted to lath house and after 2 year plants were planted in the field at University Research Farm Koont, Pakistan. Plants are healthy and are at bearing stage after four years of plantation. These plants can serve as mother plants for taking cuttings for further propagation. This technology can be a good substitute to conventional seeds.

Figure 3. Plantlet coverted from the synthetic seed

Figure 4. Olive plant after aclimatization

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Olive oil quality vary with cultivars and agro-climatic conditions

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Abstract

Three different olive varieties Pendallino, Coratina and Leccino, grown at various ecological zones i.e. Olive Model Farm (OMF), Mardan and Barani Agriculture Research Institute (BARI), Chakwal for assess the oil quality during two consecutive years, 2008-09 and 2009-2010. Means for Polyphenols, peroxide and acid value of olive oil were significantly influenced by cultivars and locations of olive production. The means for cultivars revealed the highest Polyphenols (186.76 ppm) for cultivar Pendallino followed by 115.76 ppm and 85.71ppm with cultivar Leccino and Coratina respectively. The oil of cultivar Coratina had the highest peroxide (18.50 milli eq/kg) and acid value (2.65%). By contrast, the least peroxide value (12.75milli eq/kg) and acid value (2.49%) was recorded in oil extracted from of cultivars Pendallino and Leccino respectively. The interaction of olive cultivars and location of production revealed significant influence on the all the three parameters under study. The Polyphenols of olive oil were significantly higher in cultivars Leccino (165.62 ppm) and Coratina (112.87 ppm) grown at Sangbhatti and declined to 65.90 ppm and 58.55 ppm accordingly when the same cultivars were grown in Chakwal location. By contrast, Polyphenols in oil of cultivar Pendallino was lower (139.75 ppm) at Sangbhatti but higher 233.84 ppm at Chakwal location. The opposite trend was observed in peroxide value which was lower in oil of cultivars Leccino and Coratina (7.53 and 9.80 milli eq/kg respectively) but increased to 23.11 and 27.21 milli eq/kg in oil obtained from Chakwal location. While the peroxide value of cultivar Pendallino was not affected significantly. The acid value of olive oil was the least (0.85%) in cultivar Leccino and the highest (2.89%) in Pendallino at OMF, Sangbhatti location.

Key words: Olive; oil quality; locations; cultivars

Introduction

Olive fruit is a rich source of nutrition and its therapeutic properties (Ashraf *et al.,* 2004). Olive oil reduces LDL and increase HDL because it contain sufficient amount of o C18:1cis (Keys*et al.,* 1986). It also contains high amounts of phenol and Vitamin E, which decline the degeneration of human body cells (Kiritsakis *et al.,* 1998; Keceli and Robinson, 2002). Olive oil greatly stabile of against oxidation during storage is attributed to the presence of polyphenols (Argenson, 1999). Total edible requirement of Pakistan is 3.53m tons out of which our local production is 0.87 million tons (Anonymous, 2010) and import 2.67 million tons, with the cost of 2.50 billion $ annually (Khan *et al.,* 2008). Several other oil producing crops i.e, soybean, canola and sunflower, etc have been introduced, but it could not be substitute of traditional crops (Awan *et al.,* 2011). Quality oil depends on the fatty acids compositions, phenolic compounds, peroxide value and acidity and may be influenced by different varieties (Ayton *et al*., 2001) and location of the production (Sweeney *et al.,* 2002) due to changes in elevation (Freihat *et al.,* 2008) and environmental factors during plant growth and ripening (Tovar *et al*., 2002). The olive oil is a rich source of phenolic compounds such as hydroxytyrosol, 3, 4- DHPEA), tyrosol and simple phenolic acids. The phenolic compounds content is an important quality attribute of olive oils because it contributes to oil flavor and causes resistance to oxidation, bitterness and pungency of olive oil taste (Kongoli, 2011; Morello *et al.,* 2004), thus its stability (Shahidi and Wanasundara, 1992). The phenolic content of olive cultivar, may vary with cultivars, maturity stage at harvest (Tous *et al*., 1999), year of harvest and hence the quality of olive oils (Morello *et al.,* 2004; Lerma-Garcia *et al.,* 2009). The phenolic compounds are also important because of their chemo- protective properties in human beings (Lerma- Garcia *et al.,* 2009). The total phenols are very important for the quality of extra virgin olive oil, because of their involvement in resistance to oxidation (Tsimidou, M. 1998). The peroxide value is a measure of primary oxidation and is reported to be 10.64 meq/ kg initially (Ocakoglu *et al*., 2008). The quality and stability of olive oil is determined by lipid oxidation, that is influence of multiple factors, such as light, temperature, enzymes, and metals (Gutierrez, *et al*,. 2008), over maturity (Kiritsakis, 1998), chilling exposure (Osman *et al.,* 1994) climatic conditions (Sweeney *et al.,* 2002). Thus, the study was initiated to assess the best oil quality of olive varieties grown at various locations varying in altitude, temperature, rainfall and humidity.

Materials and methods

For oil quality analysis the oil obtained from the fruits of different varieties from both locations and extraction was done through pressing method and analysis was done at PCSIR, Peshawar. Two years data were combinally analyzed according to the procedure appropriate for by CR design. Mean were compared when F test were found

significant (Jan *et al.,* 2009). The oil quality was evaluated according to the procedures described in Association of Official and Analytical Chemistry (AOAC, 2000).

Extraction of polyphenolic compounds

The phenolic compounds from olive oil were extracted according to the method of Pirisi *et al*. (2000). During the study 30 ml of Methanol/H_2O (80:20) and hexane (30 ml) were added. After the addition it were mixed for 2 min, and then centrifuged at 5000 rpm for 10 min, and was repeated the process. The two phases were then separated through pipette. The separated methanolic phase was then concentrated under vacuum at 30°C and was dissolved in acetonitrile (10 ml) and washed twice with hexane (20 ml) and the solution was then concentrated under vacuum at 38 °C till dryness. The dried residue was dissolved in MeOH (1 ml) and subjected to colorimetric for analyses of phenols. The polyphenols in the methanolic extract solution was estimated with the Folin-Ciocalteu reagent using gallic acid as a calibration standard. For this 0.1 ml of aliquot was added with 5 ml of water followed by the addition of the Folin-Ciocalteu reagent (0.5 ml). After that 3 min, 1 ml of an aqueous Na_2CO_3 solution (35 g/l) was added and mixed vigorously. The tube was kept at room temperature for 1 hour (Del Carlo *et al.,* 2006). A blank experiment was carried out through same method.

Determination of peroxide value (POV)

The per oxide value was determined by the method described by Metcalfe *et al*. (1966). Oil sample (0.5 g) was taken into a 250 ml flask and 30 ml of acetic acid and chloroform (3:2) solution was then added. Saturated potassium iodide (0.5 ml) was added and the solution was shaken for 1 minute. Add distilled water (30 ml) to the solution and was titrated against 0.1N Sodium thiosulfate till the yellow color was disappearing. 2 ml of starch solution was added to the sample and titration continued till the color was discharged. A blank without sample was also titrated against 0.1N sodium thiosulfate. The blank titration was not allowed to exceed from 0.1 ml of the 0.1N Sodium thiosulfate solution.

S= Sample for titration
B= Blank
N= Normality of sodium thiosulfate

$$POV = \frac{(S - B) \text{ x } N \text{ x } 100}{\text{Wt of sample in gm}}$$

Results and discussion

Polyphenols (ppm):The analysis of olive oil revealed significant variation in Polyphenols contents of oil of olive cultivars and locations as well as the interaction between cultivars and Locations (C×L). Cultivar Pendallino had the highest mean Polyphenolic content (186.79 ppm), followed by Leccino (115.76 ppm) whereas Coratina had the least Polyphenols (85.76 ppm). Polyphenols were higher (139.43 ppm) in oil at location Sangbhatti as compared to (119.45 ppm) in Chakwal. The Polyphenols of olive oil were significantly higher in cultivars Leccino (165.62 ppm) and Coratina (112.87 ppm) grown at Sangbhatti and declined to 65.90 and 58.55 ppm accordingly for oil of the same cultivars, grown in Chakwal location. By contrast, Polyphenols in oil of cultivar Pendallino was lower (139.75 ppm) at Sangbhatti but increased 233.84 ppm at Chakwal location. The overall C×L interaction revealed that the maximum Phenols (233.84 ppm) for cultivar Pendallino at location Chakwal, while it was the least (58.61 ppm) in oil of cultivar Coratina at same location (Fig 1). The polyphenols are important for the quality of oil and higher values are correlated with increases shelf life of the oil (Gomez *et al.,* 2008). It was noted that the Polyphenols ranges from 50 to 1000 mg/kg (Boskou, 1996), which affect by various factors such as environmental factors, varieties, ripeness and processing, after storage of the oil (Gutierrez *et al.,* 1999; Alessandri, 1997; Parlati *et al.,* 1994; Tous and Romero, 1993). The variations in polyphenols in different cultivars due to their genetic differences of cultivars and location indicated different oil quality (Youssef *et al.,* 2010) and could be due to climatic conditions (Pannelli *et al.,* 1994).

Per Oxide (milli eq/kg): The Per Oxide value of the oil was significantly affected by varieties, site of location and their interaction (C×L). The highest mean Per Oxide value (18.50 milli eq/kg) was recorded in oil of cultivar Coratina, followed by Leccino (15.32 milli eq/kg) whereas oil of cultivar Pendallino had the least Per Oxide (12.72 milli eq/kg). The mean Per Oxide value was higher (20.81milli eq/kg) at Chakwal than 10.21 milli eq/kg recorded for Sangbhatti (Table 1). In C×L interaction, the highest per oxide value (27.21 milli eq/kg) was recorded for oil of cultivar Coratina al location Chakwal, while the least peroxide value (7.53 milli eq kg^{-1}) in oil extracted from olive cultivar Leccino grown at Sangbhatti location (Fig 2). The Per Oxide value (POV) of the olive oils is below 20 meq of oxygen/kg of oil and accepted as the quality virgin olive oil (IOOC, 2003). These per oxide value of olive oil of cultivars is determined by genotype x environment interaction (Ranalli and Angerose, 1996) and fruits quality as influenced by mechanical injuries due to insects and pests, improper systems of harvesting, transport and storage (Kiritsakis, 1998). At Chakwal the POV value exceeded from the limit may be attributed to the environmental conditions of that location (Ramezani, 2008). The per oxide values of the oil observed during the course study are below the standard limits for extra virgin olive oils (EEC Regulations) except at Chakwal location.

Acid Value of olive oil: The mean acid value of the olive oil was not significantly different among the olive cultivars under study but was significantly higher (2.95%) at in olive oil for location Chakwal as compared to 2.15% observed for olive oil obtained at Sangbhatti (Table 1). In C×L interaction, the highest acid value (4.14%) was recorded for oil of cultivar Leccino grown at location Chakwal that declined to the least acid value (0.85%) in oil extracted from the same cultivar, grown at Sangbhatti location. By contrast the acid value of the oil of cultivar Pendallino (2.89%) decreased significantly to 2.14%, when the same cultivar was grown at Chakwal location. The acid value of oil from cultivar Coratina was not significantly affected by the two locations ((Fig 3). Acid value influences the quality, typically the shelf-life parameters of olive oil. Acid value can be affected by different variables like temperature, altitude, latitude, soil texture and composition, method of extraction and storage(Rondanini *et al.*, 2011). However some of the published data showed that year, location, latitude, longitude, elevation do not show significant correlations with individual quality parameters and when data from different varieties were considered(Ranalli *et al.*, 1999). In case of our studies all the above variables more or less are responsible for the variation in acid values of different varieties.

Tables 1: The interaction of olive cultivars and production location on the polyphenols, peroxide and acid value of olive oil.

Cultivars	Polyphenols	Peroxide Value	Acid Value
Leccino	115.76	15.32	2.49
Pendallino	186.79	12.72	2.51
Coratina	85.71	18.50	2.65
LSD at	12.309	0.902	Ns
Location			
Sangbhatti	139.41	10.22	2.15
Chakwal	119.43	20.81	2.95
Significance	10.050	0.736	0.225
C x L	*	*	*
LSD	17.407	1.275	0.389

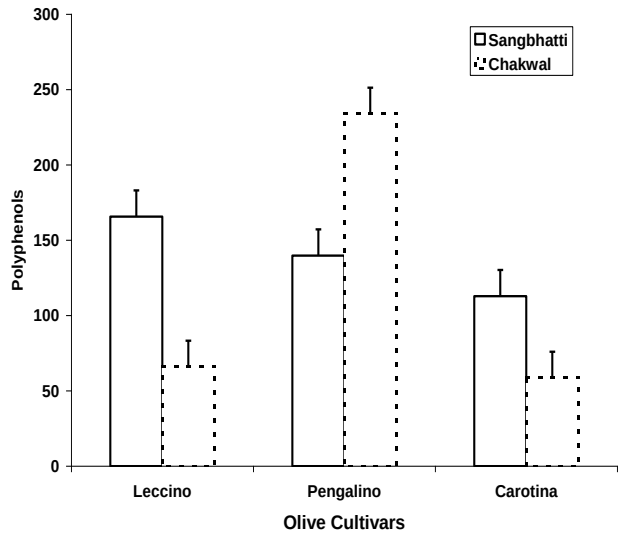

Figure 1. The interaction of olive cultivars and production location on the polyphenols

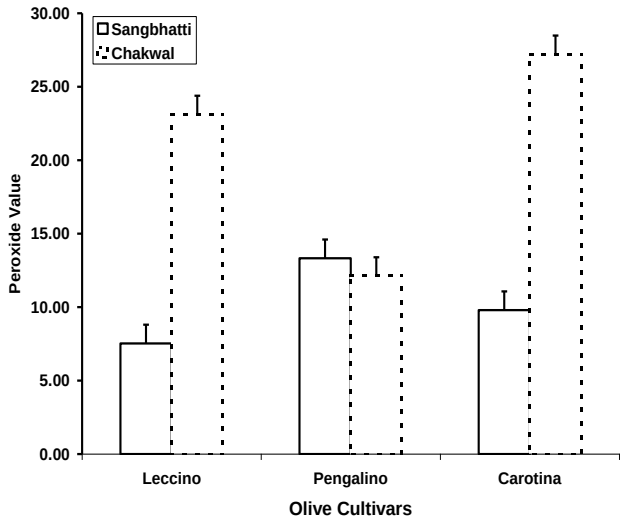

Figure 2. The interaction of olive cultivars and production location on the peroxide value

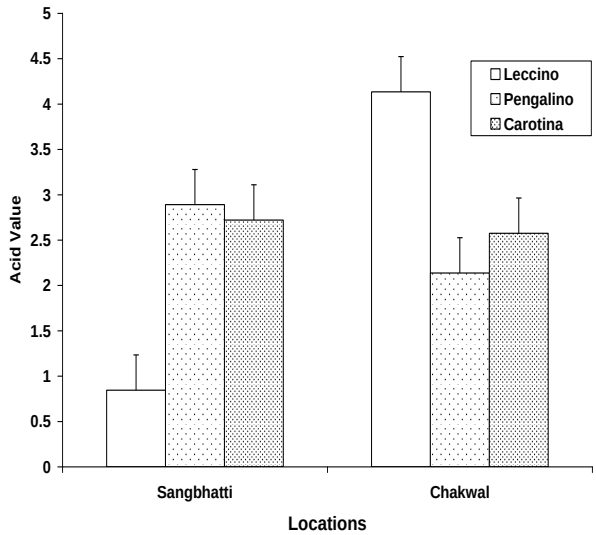

Figure 3. The interaction of olive cultivars and production location on the acid value

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Establishment of nursery for vegetative propagation of *olea europaea* l.

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Abstract

Vegetative propagation of olive (*Olea europaea* L.) is simple and easy by adopting scientific techniques. Optimum level of soil nutrients and suitable soil texture enhance vegetative growth of olive. The present study was carried out at PMAS Arid Agriculture University Rawalpindi, Pakistan for establishment of olive nursery. Nursery of different cultivars of olives was raised in a semi controlled mist propagation tunnel. Stem cuttings of five desired species were obtained from at Barani Agriculture Research Institute Chakwal, Pakistan. Mist irrigation technique was adopted for supply of proper amount of water to the plants and humidity maintenance inside the tunnel. Bari-1 cultivar of *Olea europaea* L. performed better as compared to other four varieties. Bari-1 attained maximum leaf area per plant in 130 days. The maximum number of plants was also sprouted of Bari-1. Leccino cultivar attained maximum number of leaves per plant. Soil treatment R1 was better than other for vegetative propagation of olive.

Key words: Nursery; propagation; growth; olive

Introduction

Olive (*Olea europaea* L.) belongs to botanical order scrapulariales family *Oleaceae* which has 30 species (Luchetti, 2002). Olive is propagated through sexual and asexual reproduction. Propagation of olive through sexual mean is usually not recommended, because seedlings are not true to type and take a lot of time to bear fruit. Asexual or vegetative propagation is widely used commercial method of propagation for olive (Ahmad *et al.*, 2014). The eastern Mediterranean countries including Greece, Cyprus and Turkey had olive cultivationfor the *time before the historical records*. The cultivation in northern Mediterranean countries including Italy, Spain, Algeria and Egypt began later than in the eastern countries (Seyhan and Gezerel, 2005). There are five main olive producing countries in the world e.g. Spain, Italy, Greece, Portugal and Tunisia. Leading olive producing countries of the world are Spain and Italy (FAO, 2009). Olive has commercial as well as religious value. Hazrat Abu Huraira (R.A.) recounted that Prophet Muhammad (S.A.A.W) uttered "Eat the olive and massage its oil over your bodies since it is a holy tree" (Sarfaraz *et al.*, 2009). This was the main reason that Arabs gave it great attention and planted olives in every appropriate region of Mediterranean basin (Baloch, 1994). Olive branches are also displayed on United Nations logo as a symbol of peace.

Olea ferruginea is a broad-leaved tree species native to sub-continent (India and Pakistan) and distributed from 400 to 2000 m height in dry-temperate and moist-temperate regions of Pakistan. More specifically, this species is distributed along the Afghan border, Western hills of Baluchistan, Dir, Chitral, Salt range, lower hills of Azad Kashmir, Waziristan, Swat and Murree hills (Sheikh, 1993: Zabihullah *et al*., 2006). This wild olive locally known as "Kahu" is not fruit bearing. Government of Pakistan has shown its keen interest in promotion of olive cultivation in Pothwar region. Fifty thousand acres to be planted in next 10 years under government of Pakistan vision 2025. It is important that only 10 % of farmer's demand for olive cultivation is being fulfilled by public sectors and certified varieties. And rest of the farmers has to rely on private sectors and uncertified varieties which after 5 to 6 years may not be fruit bearing. Healthy and certified plants produced from authentic mother plant sources are the need of the hour to bridge this gap of supply and demand.

This study was planned with the following objectives:

1- Establishment of nursery of authentic varieties from vegetative propagation of *Olea europaea* L.
2- Todetermine the phonological characteristics (days to sprouting, number of leaves and leaf area) and the growing habit during vegetative propagation of *Olea europaea* L.

Materials and methods

Study area

The present study was carried out at PMAS Arid Agriculture University Rawalpindi, in the province of Punjab, Pakistan. District Rawalpindi is located at latitude 33°40'N and longitude 73°15' E respectively (Farkhanda and Saeed, 2006). Stem cuttings of five cultivars of *Olea europaea* L. was obtained from Barani Agriculture Research Centre (BARI), Chakwal, Pakistan.

Methods

A semi controlled tunnel with mist irrigation system was established to maintain suitable temperature and humidity and for efficient use of water. Mist propagation tunnel had length of 15 ft. and a width of 10 ft. This tunnel is enough for the production of ~5000 saplings. The tunnel was covered with green net and polythene sheet as required to maintain the suitable environment. Thermo-hygrometer, fogger, iron rods were installed with a cost of ~20000 (PKR). Thermo hygrometer was used to measure temperature and humidity on daily basis. Hardwood cuttings of five olive cultivars (Table 1): Bari-1, Leccino, Ottobrattica, Pendolino, Gemlik*)* were transplanted into polythene tubes filled with a mixture of sand, silt and decomposed farm yard manure as mentioned in Table 2. Four treatments of soil mixture were used in this study (Table 2). Polythene tubes were kept in beds of size 5x10 ft. (width and length). The propagation in polythene tubes was preferred due to ease in transport.

Olive cuttings were dipped in solution of growth hormone (i.e. IBA) having concentration of 4000 ppm. IBA solution was prepared in 0.5 % NaOH solution. Humidity (45-65 %) and efficient use of water was maintained with the help of mist propagation technique. Temperature was maintained: + 9 °C to + 12 °C (February/March) during Sprouting and+ 14 °C to + 16 °C (March/April) during bud growth.

Table 1: Varieties of *Olea europaea* L. and their origin

S. No.	Name of Variety	Origin
1	Bari-1	Pakistan
2	Leccino	Italy
3	Ottobrattica	Italy
4	Pendolino	Italy
5	Gemlik	Turkey

Table 2: Growing media (soil) composition (%) used in this study

Treatments	Sand %	Silt %	Farm yard manure (decomposed)%
R_1	50	25	25
R_2	33	33	33
R_3	50	0	50
R_4	0	50	50

Phenological prameters studied

Days to sprouting and leaf growth was recorded by randomly selecting five plants from each variety. The data on number of leaves/plant was recorded by counting and taking average of sample. The data of for leaf area per plant (cm^2) was also estimated. To determine the leaf area, length of leaf (cm) was measured along the lamina midrib, from the point of lamina attachment to the tip. Leaf width (cm) was measured perpendicularly to lamina midrib, from edge to edge at the widest part of the lamina (Dheebarkran and jagnathann, 2009). Leaf area was calculated using a general relationship as mentioned in Eq. 1(Montgomery, 1911).

$$A = b \times L \times W \quad \text{Eq. 1.}$$

Where b is a coefficient taken as 0.74, A is leaf area, L is leaf length, and W is width of leaf. Total leaf area of a plant was estimated by taking sum of all leaves area. The data collected about pheneological characteristics was subject to statistical analysis.

Figure 1. Emergence of new leaves and shoots in cultivar Bari-1

Figure 2. Emergence of new leaves and shoots in cultivar Pendolino

Figure 3. Emergence of new leaves and shoots in cultivar Ottobrattica

Figure4. Number of roots, root length, number of shoots, shoots length in Bari-1 after 120 days of its emergence

Results and discussion

Fig. 1 to 6 are presenting visuals taken during study. Significant difference were observed among the varieties for days to sprouting of vegetatively propagated olives as shown in Fig. 7. Cultivars are on x-axis and number of days to sprouting on y-axis. Analysis of data showed that minimum number of days for sprouting was 27 as observed with Bari-1 while Pendolino took 37 days (maximum) for sprouting. Further, Bari-1 performed better with R1 soil type compared to other treatments. All cultivars sprouted earlier with R1 soil type than other three soil types (Fig. 7).

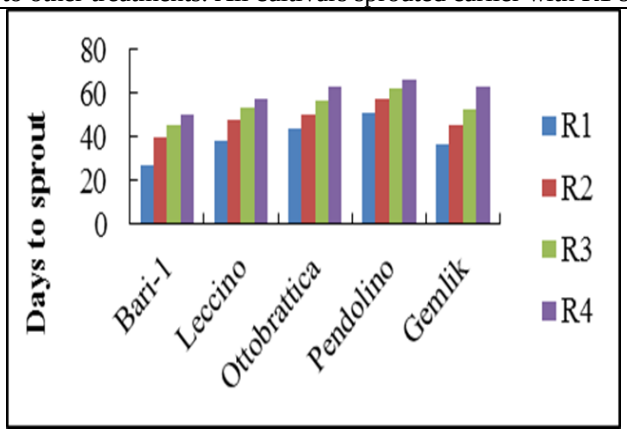

Figure 7. Days to sprout of five olive cultivars with four soil types

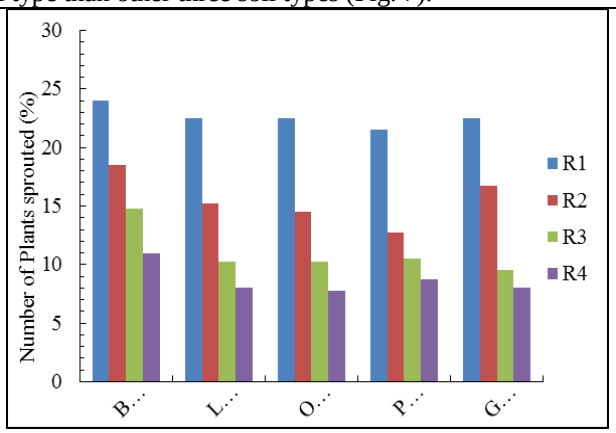

Figure 8. Number of plants sprouted of five Olive cultivars with four soil types

Significant differences were observed among the cultivars for number of plants sprouted (Fig. 8). Analysis of data showed that Bari-1 had maximum number of plants sprouted was 24 %, other cultivars showed almost similar performance (22-23%) with R1 soil type. The minimum plants sprouted were of Gemlik cultivar with R4 soil type (Fig. 8).Fig. 9 showed that Leccino cultivar has maximum number of leaves per plant: 17 with soil R1 while variety Ottobrattica has minimum number of leaves per plant: 3 with soil type R4 (Fig. 9).

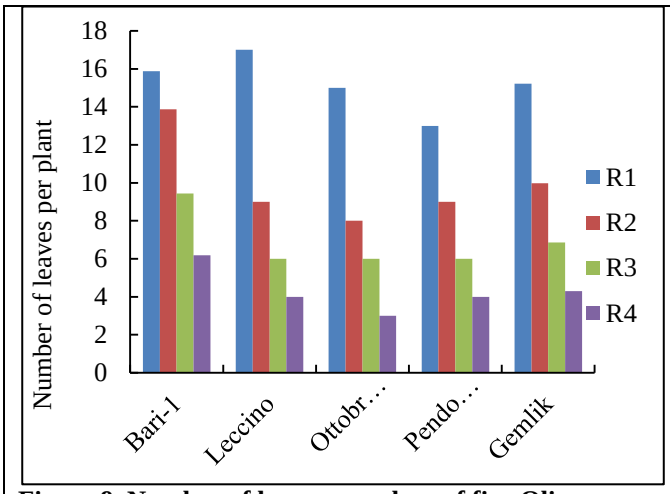

Figure 9. Number of leaves per plant of five Olive cultivars with four soil types

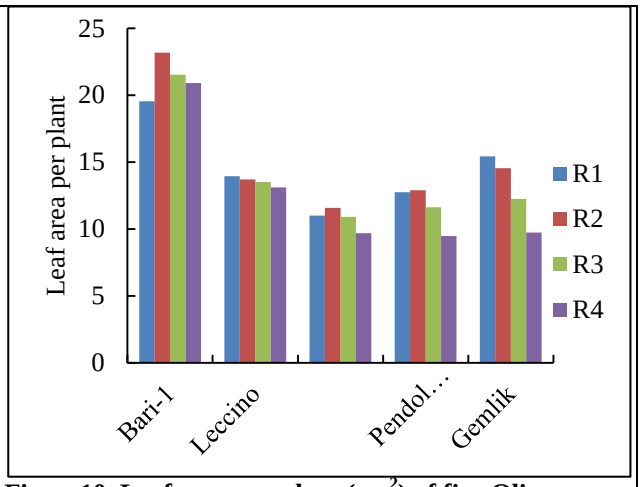

Figure10. Leaf area per plant (cm^2) of five Olive cultivars with four soil types after 130 days of sprouting.

Analysis of data indicated that Bari-1 has attained large leaf area per plant (23.17 cm^2) With R2 soil type, while variety Pendolino has least leaf area per plant (9.47 cm^2) with R4 soil type (Fig. 10). The leaf area was estimated after 130 days of sprouting.

Conclusion

Vegetative propagation of olive is easy and economic way of producing authentic plants from authentic mother sources. Mist propagation tunnel is easy to install and it is necessary for efficient use of water. Bari-1 cultivar of *Olea europaea* L. performed better as compared to other four varieties. Bari-1 attained maximum leaf area per plant in 130 days. The maximum number of plants was also sprouted of Bari-1. Leccino cultivar attained maximum number of leaves per plant. Soil treatment R1 is better for vegetative propagation of olive.

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Available and innovative technologies against soil erosion and desertification and A brief overview of olive tree worldwide and diffusion prospects in Pakistan

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Abstract

The first part concerns technologies developed in Italy for improving water harvesting and utilization in semi-arid areas and some special micro-irrigation devices for improving horticultural and fruit crops development and production. The second part concerns the history, diffusion and development in the world of the olive tree and the specific requirements of this crop for improving production of olives for both oil and direct utilization. The presence in Pakistan of a close wild relative of the cultivated olive and of several semi-arid ecological areas, could represent an important advantage for its diffusion in several adapted areas of the country. It is particularly suggested to increase the collection of cultivars, particularly from Mediterranean areas with similar characteristics and to develop the exchange of experts particularly from some Mediterranean Countries and from some areas of Pakistan, using both International (FAO, IFAD) and National Cooperation Institutions.

Key words: Soil erosion;water harvesting; semi-arid regions; desertification; olive

Part A. Available and innovative technologies against soil erosion and desertification

The diagnosis of the problem

An enormous amount of research contributions is now available regarding the process of soil erosion and desertification, now more and more evident particularly in arid and semi-arid areas of all Continents. These phenomena are mainly related to scarcity or excess of rainfalls, normally associated to eolic and water actions, reduction or excess of soil rainwater imbibitions, gradually leading to vegetation disappearance and desertification. It is now clear that the most important problem of these areas is the soil erosion or degradation, which is limiting plants survival. This situation favors also the sterilization of soil microflora, the mineralization of organic matter and soil chemical deterioration (like salinization) to lead, finally, to complete sterility and permanent desertification.

There are well known three basic interpretations of this phenomenon: A first one, which underlines the importance of the past climatic cycles of the planet,the second underlines man's activities and behaviors as the present main cause of these events and therefore the possible remediation by changing the human bad impact and stile of life, while the third one, thinking that desertification process is caused by both the natural climatic conditions and changes and the present human behaviors.

In fact, we should remember that, during the last half a million years the planet has witnessed five glaciations periods, each lasted some 90-100 thousand years, followed by inter-glacial periods normally lasted some 10.000-13.000 years. In such previous 4 periods influence of man's activities was certainly not involved. We are now living in the 5th inter-glacial period since 10.000-12.000 years, but we do not know if and when a new glaciation period could or would be present.Now we can only verify that the planet is witnessing a gradual increase of its temperature, likely connected with the continuous increase of release of "greenhouse gases" mainly derived from increasing fossil fuels utilization and to deforestation of several million hectares, mainly in tropical and subtropical areas.We do not know what could be the future climate of our planet, the possibility or not of a new glacial period, favored or not by the present heating of the oceans and atmosphere. Several hypothesis are possible, but only on theory.However, in the last decades we have been witnessing, particularly in several arid and semi-arid areas of the globe, periods of high scarcity of rainfall, responsible of the increase of desertic areas, particularly involving southern areas of Sahelian Africa, Near and Far East, Australia, the semi-arid plains of USA etc.

FAO classification of arid and semi-arid lands

An FAO document, released in year 2000, has subdivided the lands of the planet in "arid", "semi-arid" and "dry-subhumid", based on the length of the period in which are possible annual land cultivation. It has been established that the period of growth of plants in such zones can start and continue only when monthly rains are higher than half the potential evapo-transpiration verified in the same period.

Therefore have been classified as "arid" regions where, regularly, are present at least 60 days of growth; as "semi-arid" regions of between 60 to 120 days and "dry-subhumid" lands with 120-180 days normally useful for plant

growth.FAO then classified as "arid" zones 7% of the total world area, as "sub-arid" 20% and as "dry-subhumid" 18%. Therefore, altogether, lands with possible crop growth between 60 and 180 days, represent 45% of total world land. However, in such areas, are living some 38% of the total world population (2,3 billion people), while the other 4,7 billion are living in areas of higher rainfall (55% of available land). As previously mentioned, there are now available an enormous amount of documents particularly on the "Diagnosis" of erosion and desertification and on the continuous increase of lands affected by drought in all populated Continents. Moreover, considering that more than a third of world population lives in such areas, such a problem deserves much more attention than in the past. Certainly, if, at the moment, we cannot front macro-phenomena like glaciations, we should be more concerned with possible solutions for limiting and contrasting an increase of desertification likely induced by present human activities.

Available and possible Innovative Therapies

Therefore, it is necessary to better focus our attention on possible "Therapies" to be applied to the concerned areas in the various Countries and Continents affected, in order to limit and possibly revert the process of soil erosion and desertification, considering the various technologies developed in the past, but particularly in the past century and implemented in several developed countries (USA, Australia, Israel etc.), but also in several developing countries (China, India, Near East, Sub-Saharian, South and Central American Countries etc.). Then, we must abandon an academic approach for practical contrasting and repair actions.

USA scientists have been, in the first half of the last century, first to develop a rational and scientific approach for soil erosion and desertification control, involving important financial resources, for solving such a problem in their Country.Before the discovery of the American continent, local human nomadic populations (hunter-gatherers)) were living in North America in close association with the buffalos, the largest herbivorous mammal present in this area and source of their basic food and skins. In fact very large areas of present US were represented by semi arid steppes, where large buffalo herds were using grasses for their feeding, going north in spring-summer and getting back to southern areas in fall-autumn. There was a natural equilibrium between feeding vegetation, bison and man, besides some minor animals.

Horses were introduced after America's discovery together with donkeys, bovines, sheep and goats, other small ruminants and chicken, the only local large edible birds represented by turkey and local ducks. With the European colonization were also introduced the main crops of the old world (both for human and animal feeding) together with the European farming systems and the introduction of soil cultivation with ploughing of the soils. After the cultivation of most fertile and humid areas, were then cultivated also more arid marginal steppe areas, before mainly covered with perennial grasses, normally using the rotation: old world cereals and fallow (used for rainwater accumulation). Replicated ploughing for fallow weed control and the short vegetation cover in the two or more years involved, were favoring large eolic and water soil erosion, with the loss of the fertile superficial soil, involving very large areas, before covered mainly by perennial natural vegetation. The cereal-fallow utilization of these steppe semi-arid areas had the top from 1915 to 1925 in the "Great Plains "of USA, also because the increased market demand of cereals and also because of a temporary increase of rainfalls above the average. Unfortunately, after the sub-humid decade was following, in the '30ths, a series of years with lower rainfalls and the need of much longer fallows for rainwater accumulation. This period was called the "Dust Bowl Era", because of the occurrence of very high eolic erosion, followed by rainwater erosion, sterilizing some 2,5 million hectares.

Agronomists realized that these areas should be reverted to permanent pasture utilization. It was possible to have cereals or other crops cultivation only when irrigation water was available. Also in the '40's, because of the 2nd world war food demand, such an erosion was again present, but at lower level. To avoid erosion, a series of land management technologies were applied, following the hill's contours and leaving larger stripes of areas covered with selected perennial grasses, adapted to these semi-arid conditions and useful for a controlled pasture utilization by both cows and smaller ruminants. Nowadays the promoted so called "Conservation Agriculture" is based on 3 main factors:

1) Zero tillage and sod seeding.
2) Conservation of a permanent land "green cover", by using perennial adapted grasses and legume species.
3) If land is cultivated utilizing crops rotations, it was important to leave residual biomass on the top of the soil for its protection, improvement and moisture conservation.

It is evident that such technologies are valid particularly if human and animal population are rather low and the area available per living persons and cattle is high, as we have in large zones of USA and south America. Also in Australia similar desertification events were induced, particularly in semi-arid areas. In this continent, moreover, before the European colonization, large mammals were not present. With the introduction of bovines, sheep and goats, horses and rabbits and of crops of the old and new world, together with the European agronomical practices, in the large semi-arid areas of the continent very important soil erosion events were witnessed. However, in Australia was developed a particular soil-conditioning instrument, the "chisel plough". The normal European plough was substituted by one or more big and long (50-80 cm) teethes, pulled by a normal tractor. This instrument is breaking the crust, moving the soil, facilitating water penetration. but it maintains rather undisturbed the soil layers and the soil's microflora. Such a tool can be used in alternative stripes, worked and not worked, which should be larger in more arid zones. The rainwater will run in areas not worked and will penetrate in the worked areas in larger amount, where vegetation life could be easier. This type of technique, providing the so-called "rainwater harvesting" could be particularly useful for reforestation or

for pasture regeneration in several areas also of Sahel, Near and Middle East, North and South Africa, Southern Brazil etc.
Nowadays, the rainwater harvesting utilizes two basic technologies.
The first one is involving the channeling of rainwater to a more or less large basins where it could be stored as drinking water for human and livestock utilization or for local crop irrigation.
The second one is using the realization of micro-basins or of small holes, originally made by hand (like the "zai" in Western Africa) and now also making mechanically some ditches, to trap and accumulate inside the soil running rain, providing more moisture to the crops then seeded or transplanted close to the ditches.
The first technology was already used by Nabateans in Near East some 3.000 years ago and also by central and south American pre-Colombian populations and, in the past, also in India, China, Laos etc., allowing the development of civilizations lasted several centuries also in areas of lower precipitations. The same technology has been recently adopted also by Israeli, Australian and other Countries agronomists, eventually also combined with drip irrigation. However, since in tropical areas ponds water evaporation is very high, it is possible to limit the evaporation by covering the water area with floating plastic (e.g. with polystirol tables). With this system I was able to save the water in central Brazil even for 1-2 months.The second one is to conserve the rainwater in small holes or in micro-basins where the crop is grown. It is obvious that the mechanization for production of these micro-basins was developed in order to facilitate the realization of these devices.

This mechanization has been developed by Dr. Venanzio Vallerani, an italian agronomist recently deceased, and by the Nardi agricultural machine firm, developing two special tractors and ploughs (called Delfino and Treno) with the plough automatic penetration into the soil and then emerging on the soil surface, in order to excavate basins of some 5-7 meters length and 50-70 cm deep, leaving some 1-1,5 meters of sod soil in the interval (thus avoiding the running out of the water). The distance between the furrows is modified in function of the average rainfall in the area or if the area is more or less hilly. Such mechanical devises are producing micro-basins with high efficiency and speed in proper soils (but not stony or sandy) and easily in large State owned areas and can be used, particularly for reforestation or pasture development or re-greening in general.

For re-forestation, generally made by Forestry national staff, can be used preferentially several adapted legume trees (like several species of *Acacia*, *Prosopis* etc.) eventually providing also some particular products (like arabic gum or usable fruits or seeds) besides wood and biomass, as performed, in the '90s, in 5 Sahelian Countries, by the FAO-AGRFOR "Acacia 1 Project". These species, in fact, were instrumental also in providing nitrogen and organic matter to the soil and then to re-establishing the bio-coenosis with soil microflora. Similar programs were realized by Vallerani also in China and also in several countries of the Near East, also in collaboration with ICARDA. Eventually, to further increase the growth of young trees, after 3-4 years from seeding or transplanting, the micro-basin equipment could be used again to produce new furrows at 1-1,5 meters from the previous ones for new rainwater capture, if the previous ones were not efficient anymore.

In areas already, or even partially, utilized by local farmers for crop production, I have developed a simpler solution to obtain the same results. Micro-basins can be realized using normal tractors present in the area and normal soil revolving ploughs, producing continuous furrows, which could be manually closed every 5-7 meters by local farmers (to avoid water running out). Such simple and less expensive mechanical equipments, often already available *inloco*, involving also local farmers' collaboration for their realization, could improve substantially food crops local production. In fact, also the area between the furrows can be labored both with animal energy or manually and then seeded with several species of food crops and utilized also in the following seasons, also by manually maintaining the basins. It is obvious that such technologies can be utilized if the soil conditions and rainfall are appropriate, considering also particularly the local people soil management and habits, besides their contribution to the best utilization of the local resources, certainly improved and more diffused by the utilization of proper mechanical and animal energy.

Technologies for re-greening slopes and contrasting erosion

Superficial land erosions are quite widespread and closely related to weather characteristics of large tropical, subtropical and temperate areas, where rainfalls often represent the more aggressive agent (water erosion).
The intensity of erosion action depends on several factors, such as duration and intensity of rainfall, length and angle of slope, soil permeability and intrinsic fragile soil structure, its degree of saturation, the absence of vegetation etc.
Moreover, the intense erosion eliminates the superficial more fertile soil and accelerates the leaching of nutrients, making very difficult the vegetation growth. The anti-erosion techniques today's most popular, particularly in developed countries, were mainly developed by engineers and were developed from 1950-'60. Most involve the use of synthetic products such as concrete walls and plastic or wood geo-cells, geo-mats, geo-nets, etc. which, however, in difficult climatic conditions, besides being very expensive to establish and maintain, may not solve the problem of erosion and do not allow a rapid controlled re-greening.

In recent years, considerable interest is attributed to anti-erosion interventions that use natural systems, such as the utilization of perennial grass species adapted to specific soils and to local agro-meteorological conditions. In fact, recent developments have highlighted the ability of some deep-rooting grass species to grow also in prohibitive conditions, where normal plant species cannot survive, thus being able to very effectively prevent the superficial soil erosion. These plants would behave as pioneer organisms, developing even on sterile and contaminated soils, being able

to develop a dense vegetation cover and so improving the improvement of soil structure and fertility. The soil would therefore become more suitable to colonization by most demanding plant species (such as shrubs and trees) accelerating the process of naturalization and environmental restoration. In fact, the role of vegetation in protecting slopes from superficial erosion since long has been studied and documented by experimental research.

The first species, since long time utilized in the humid tropics, has been the Vetiver (*Vetiveriazizanoides*), a grass original from the Gangetic basin, in India, provided with many very long, dense and robust roots, (initially utilized for extraction of a perfume from the roots), and then selected for sterility (non production of seeds, to avoid to become a weed) and, therefore, to be multiplied vegetatively. Million of hectares are now stabilized with this crop in tropical Asia, America and Africa. However, being a tropical species, is not adapted to worm-dry and cold areas.In Italy, a firm located in Milano (www.pratiarmati.it) since more than 30 years, has developed a technology, using seeds of several selected perennial grass species specifically adapted to alpine, or temperate, or semi-arid mediterranean areas, by spraying, on the bare soils to be treated, a liquid containing the specific grasses seeds, a glue, fertilizers and pesticides (mainly against ants), able to colonize and re-greening vast bare areas and high slopes. To reduce water erosion phenomena and thus the soil loss due to water run-off, the use of deep rooting grasses is efficient for the following reasons:

a) They are living, perennial organism with a strong root apparatus.
b) Grass leaves dissipate most of the kinetic energy of rain drops, thus mitigating their erosive effects (*splash erosion*).
c) In case of heavy rainfall, a major fraction of meteoric water streams above the flatten vegetation layer, even when the leaves are dried, waterproofing the slope and substantially reducing the damage of rapid and intense infiltration of water.
d) The presence of vegetation may reduce the speed of runoff water on the soil and therefore the intensity of erosion.
f) There will be a delay in reaching the conditions of complete saturation of the soil also due to the mechanism of plant transpiration, as liquid water is absorbed from the soil by the roots and transferred to the atmosphere as vapor.
g) The soil is mechanically reinforced by the presence of living plant roots.
h) The vegetal network retains the soil particles, resulting in containment actions, filter and contrast of soil particles sweeping away.
i) The increase in soil organic matter results in a significant increase of its water retention capacity, improving the microorganisms life and provides basic factors for plant growth.

Conclusion

It seems that we have now available several technologies which could help in the control of superficial and deep erosion and desertification, using simple soil management tools and living beings (trees, grasses etc.), thus providing a better environmental condition in areas where are living a large amount of the world population.

Part B. Overview on the importance of the olive tree

Crop history and domestication

The olive tree has played an important role within history and has appeared so frequently within Mediterranean ancient mythology that even today, despite our advancements in farming and production, we are still not certain of its exact story. Scholars have argued that the formal cultivation of olive trees for oil production first occurred around 6000 years ago on the Mediterranean coasts of modern day Syria and Palestine. The trees we know today with their elongated leaves and fleshy, oil rich fruit, were probably derived from crosses between different species and bear little resemblance to its wild, bush-like ancestor even now present in many wild areas of the old world.In the present Mediterranean areas olive trees are growing and producing olives with a high number of cultivars selected by local populations since several millennia.

In fact, in the Mediterranean environment, the domesticated trees are characterized by a long life (even more then 1.000 years) and by a very well known production and oil extraction technologies done since millennia before by local farmers, now with specialized units

Prospects of diffusion in Pakistan

General considerations:

1. Olive oil is considered a high qualityproduct both as a source of fats for human nutrition and as an excellent and flavorful seasoning and therefore more and more traded all over the world also according with changes in styles and eating habits.

2. However, nowadays olive oil is competing with many other oil crops. First of all the palm oil, which is, like olive, perennial but gives very higher oil production per Ha, now very much diffused in Asia, and many other important annual oil crops: sunflower, canola, soybean, cotton etc.

WORLD OLIVE OIL PRODUCTION (except Europe)

Countries	Oil Production (x1000 tons)	% of World Production
Albania	8.1	0.3
Algeria	50.8	1.7
Argentina	23.2	0.8
Australia	15.7	0.5
Chile	14.7	0.5
Cyprus	5.2	0.2
Croatia	4.8	0.2
Egypt	7.4	0.3
Iran	4.7	0.2
Israel	22.8	0.8
Jordan	16.9	0.8
Libya	15.0	0.6
Morocco	**115.8**	**3.9**
Palestine	16.2	0.5
Syria	**166.3**	**5.6**
Saudi Arabia	3.0	0.5
Tunisia	**150.3**	**5.1**
Turkey	**168.8**	**5.7**
U.S.A.	3.8	0.1

OIL PRODUCTION IN EUROPEAN UNION

Countries	Oil Production (x1000 tons)	% of World Production
European Union	**2,117.6**	**71.7 (% of which)**
France	5.3	0.3
Greece	**285.1**	**13.5**
Italy	**447.7**	**21.1**
Portugal	67.6	5.2
Spain	**1,305.4**	**61.6**
Others	68.3	2.3
TOTAL	**2,951.8**	100

***Over 15 million acres of olive trees are planted worldwide. 90% of those around the Mediterranean area**.
The annual world olive fruits harvest is around 10 million tons. Over 1 million tons are processed as table olives and the balance is pressed to obtain olive oil.

Situation in Pakistan

In Pakistan the introduction of olive has been favored by the presence, in several locations, of a very large amount of trees of a wild species (*Olea ferruginea* or O. *cuspidata*), genetically very close to the cultivated olive, which could be used for grafting the most advanced cultivars. Therefore local scientists, since several years, are studying the cultivated oil varieties best adapted to produce olive oil also in several areas of this Country

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Possible suggestions

1. In order to promote the diffusion of olive in new countries, it is important to identify, in the traditional areas of cultivation, the cultivars which are supposed to fit better to the environmentalconditions of the areas in which the introduction is planned and to test them before diffusion
2. It will be convenient, with the help of the local Pakistan Embassy, normally present in each foreign olive Mediterranean and Asian producing Country, to identify the local most important Olive Scientific Institutions and establish a scientific collaboration on this crop. It should also be important to establish connections with the most important olive oil nurseries present in the most important olive producing countries.

Prospects of olive growth in Pakistan: Agro-climatic suitability assessment in rainfed agro-ecosystems through geospatial approaches

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Abstract

Agriculture is the mainstay of national economy of Pakistan. Opportunities for poverty alleviation in Pakistan agriculture are emerging in increasing crop productivity through site specific crop management as well as diversification from traditional crops to the high value crops like horticultural crops, oilseeds etc. The process of crop diversification could be facilitated by assessment of land suitability for the high value crops especially in the rain-fed regions. Among different high value crops Olive is an important crop. The olive oil has a significant biological value and the per capita olive oil consumption in Pakistan is increasing. Pakistan Bureau of Statistic has provided figures concerning the import of olive oil in Pakistan; more precisely 1,463 tones were imported in the fiscal year 2006/2007 while in 2007/2008 the import has reached 2,008 tones. Olive crop could be grown in the areas with well drained soils, low rainfall with moderate temperature at high altitude. Recent studies have revealed that many areas in Pakistan have the potential of olive cultivation. The success of the olive plantations, however, will depend upon the identification of areas which meet the criteria of olive plant growth. The present talk discusses the assessment of land suitability for olive cultivation in the rainfed Pothwar region of Pakistan. The methodology for land suitability involved a geospatial techniques based analysis to identify four classes of land suitability for olive cultivation i.e. highly suitable, moderately suitable, marginally suitable and unsuitable. A land evaluation procedure was implemented based on the major crop input factors like climate (annual precipitation, mean annual temperature, absolute minimum temperature of the coldest month), soil characteristics (pH, Drainage capacity, Salinity/sodicity, Depth, Texture), topography and land use type. The Geographical Information System (GIS) based suitability models specifically adapted to the local conditions were used.Embedding expert knowledge through an Analytic Hierarchy Process (AHP) about the effect of specific factors on olive growth permitted the suitable agricultural areas to be selected by means of Geographical Information Systems (GIS). The results suggest that the Pothwar area has the substantially high potential to generate work opportunities to the local farming communities which are among the poorest of the entire country as well as to improve their diet through the use of an edible oil of high biological value and earning high farm incomes.

Key words: Olive; agroclimatic conditions; prospects; rainfed area; geospatial approaches

Introduction

Agriculture is the mainstay of national economy of Pakistan. Opportunities for poverty alleviation in Pakistan agriculture are emerging in increasing crop productivity through site specific crop management as well as diversification from traditional crops to the high value crops like horticultural crops, oilseeds etc. The process of crop diversification could be facilitated by assessment of land suitability for the high value crops especially in the rain-fed regions. Different high value crops like oilseed crops have a growing demand in Pakistan and can earn high economic returns. Pakistan spends huge amount in importing edible oils to meet its domestic requirements and during the year 2013-14 2428 tons of edible oils were imported while the value of the import has reached 210841.8 million rupees (PBS, 2013-14). Among various edible oils, the olive oil has a significant biological value and the per capita olive oil consumption in Pakistan is increasing. Olives grow best in warm temperatures, and cannot tolerate extreme climatic conditions. The Mediterranean region, owing to its mild climate, contains 98% of the olive harvest and 95% of the olive oil production in the world. The annual production of olives depends on climatic conditions and the alternate bearing nature of the olive tree, which yields one-year high/ one-year low amounts (Engindeniz *et al*., 2010). Olive crop could be grown in the areas with well drained soils, low rainfall with moderate temperature at high altitude. Olive was introduced first time in Pakistan by PARC during 1986 under an Italian Project titled "Fruit, Vegetable and olive Project" funded by Government of Italy. After this project a general survey was conducted to estimate the number of naturally occurred wild olive specie "*Olea Cuspidata*" and found more than 80 Million wild Olive plants in different district of Pakistan (PARC, 2015). Recent studies have revealed that many areas in Pakistan have the potential of olive cultivation. The success of the olive plantations, however, will depend upon the identification of areas which meet the criteria of olive plant growth.

Evaluation of land suitability is a prerequisite for successful and sustainable crop production. The best land use for a particular cropland is a function of crop requirements and soil/land characteristics. Detailed soil spatial information is, therefore, required for many land management application (Burrough, 1996). It is necessary to evaluate

the land in a given agro-ecological unit for crop production under defined management system. Land management practices that can control the processes of land degradation, and their efficiency in this respect, will largely govern sustainability of a given land use (Smyth and Dumanski, 1993). Hence, sustainable agriculture would be achieved if lands be categorized and utilized based upon their different uses (FAO, 1984).The aim of the present study was the assessment of land suitability for olive cultivation in the rainfed Pothwar region of Pakistan. Geospatial techniques alongwith spatial data sets were used for categorizing the land of region in terms of suitability for olive cultivation.

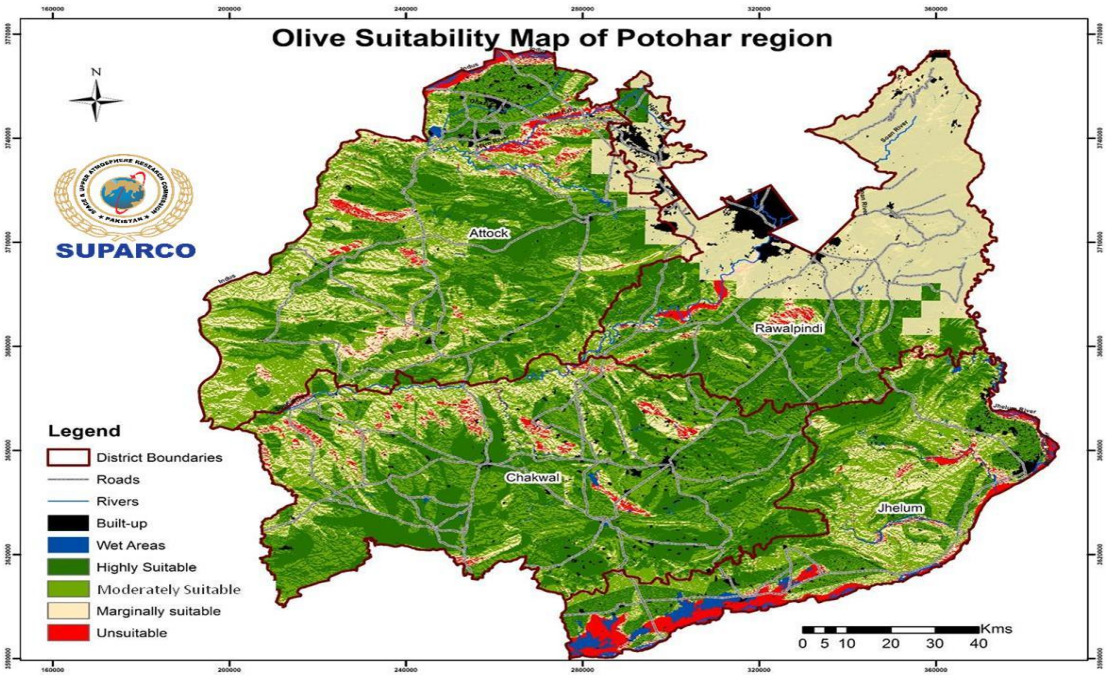
Material and methods

The study was performed for the rainfed Potohar region of Pakistan. It's a plateau between River Indus and River Jehlum comprising of 4 districts which includes Jhelum, Attock, Chakwal and Rawalpindi as shown in the Fig. 1. The Potohar Plateau included total area of 2.2 million hectares (mha). The geography of the region is undulating with average slope of 8-40% and inclined from about 32.5°N to 34.0°N latitude and about 72°E to 74.0°E longitude. The yearly precipitation in the study area varied from 450 mm in South West to 1750 mm in North East with 70% precipitation in the monsoon season (Cheema and Bastiaanssen, 2012). River Haro and River Soan are the two major seasonal stream channels flow in this plateau (Ghani *et al*., 2013) from east to the west and after crossing the region in the north and in the middle respectively, fall in the Indus. River Kanshi traverses the eastern part of the plateau from north to south and drains into the River Jhelum. Due to its deep underground water, complex topography and high drainage density the plateau is much prone to soil erosion. The plateau, being situated at the top of the world largest irrigation networks of canals and barrages i.e. Indus river system, the soil erosion can cause the sedimentation process in number of downstream barrages and canals which are very important structure for water management and flood control in Pakistan and riverine ecosystem.

Spatially explicit land suitability model, built in ArcGIS software, was used for detecting potential areas suitable for olive cultivation. The methodology for land suitability involved a geospatial techniques based analysis to identify four classes of land suitability for olive cultivation i.e. highly suitable, moderately suitable, marginally suitable and unsuitable. A land evaluation procedure was implemented based on the major crop input factors like climate (annual precipitation, mean annual temperature, absolute minimum temperature of the coldest month), soil characteristics (pH, Drainage capacity, Salinity/sodicity, Depth, Texture), topography and land use type. The Geographical Information System (GIS) based suitability models specifically adapted to the local conditions were used. Embedding expert knowledge through an Analytic Hierarchy Process (AHP) about the effect of specific factors on olive growth permitted the suitable agricultural areas to be selected by means of Geographical Information Systems (GIS).

Results and discussion

The initial results of the study show that the Potohar region have high potential for olive cultivation with around 2.12 million hectares of area suitable for olive cultivation. Among these 45% area is highly suitable, 15% area is moderately suitable and 38% area is marginally suitable while only 2 percent of the study area was found to be unsuitable for olive cultivation.



Chakwal and Attock districts of the region are found to be more suitable for olive. Northern parts of Rawalpindi district were marginally suitable because of high torrential rains in recent years during the period of January-March that affect flowering and fruit bearing of the plants. Further work is going on for the ground truthing of the results by comparing the results with the existing olive sites in the Potohar region and their potential of fruit bearing.

Conclusion

The study indicated that Potohar region have high potential of successful olive cultivation with around 60% area highly to moderately suitable for olive cultivation. Chakwal and Attock districts present the areas which have the potential of olive cultivation with high economic and agronomic returns. Accurate management practices along with high yielding varieties development could make Potohar a region of olive where promising economic returns could be gained.

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Farmers' experiences and perception on climate change in bajaur agencies-FATA, Pakistan

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Abstract

Field survey of Bajaur Agencies was conducted to document the farmers' perception about the climatic changes and its impact on crop, livestock, soil and water resources as well as their awareness. The agency is mostly hilly, rainfed with subsistence farming system and fragile security. Focus group discussions (FGD) method was adopted by inviting farmers (40- 70 age group) of three different union council (UCs). A well structured Questionnaire Proforma was prepared asking information about farmers' perception about changes in temperature, rainfall over time and space, distribution of rain fall and shifting in seasons over the last 20 years. In addition to it, the farming community provided information about the cropping pattern/sequences, yield, and use of production technologies as well as keeping of animals and the preferences for animals. Information about the land holding, water availability as well as changes in surface and ground water supplies over time were also recorded. An effort was made to get the information about the aforesaid parameters in quantitative terms. The results showed that there is significant change in cropping pattern. Some of the crops have been eliminated or are grown on limited area due to economic reasons. The major crops still are wheat (82 % area) and maize (55 % area). Opium has been eliminated completely. While some of the land that was fallow earlier has become available for cropping because of availability of irrigation water. Vegetables cultivation and production in terms of acreage and per unit area yield increased significantly due to good seed, use of fertilizers and of course improvement in irrigation water supply. Cows and goats are preferred because of better breeds and enhanced production (milk in case of cows and number of animals in case of goat as it gives birth to 2 to 3 off springs). Increase in number of animals or their preferences and improved crop yield were not ascribed to climate change rather was correlated with improved production technologies that in fact is adaptation strategy. All the respondents agreed that they have noticed changes in temperature, shifting of seasons, variability in rainfall distribution and intensity over time and space. Summer is prolonged (6.25 months) and winter is getting shorter (only 3 months) while spring and autumn have shrinked (about 1.5 and 1.25 months respectively) significantly or in some cases disappeared altogether. The monsoon rains are received about 1 month later while winter rains are received by about 2 to 3 months late compared to the past. The temperature of the three seasons (Winter, Spring and Autumn by 30, 20 and 8% increase in temperature respectively) increased while the temperature in Summer was felt decreasing (by about 10 %). Water table depth is going down (by about 20 to 30 feet). Land holding is decreasing because of land fragmentation/division among heirs.

Key words: Climate change; farmers' perception; FATA; Pakistan; crop yields

Introduction

Climate change is an overall alteration of mean climate condition observed over a long period of time, whereas the term climate variability refers to fluctuations about the mean. Climate variability is the result of interaction between climate variables over a short term and does not necessarily represent a trend. Both the climate change and variability however are threats to food supplies, sustainability of agriculture and overall food security. Agriculture sector is the backbone of the economy of Pakistan and therefore proper adaptation measures are needed to safeguard food security. The major components of food security including production, distribution and accessibility have been substantially affected by changes in both temperature (mainly rise) and rainfall (in time space and intensity (Mahmood *et al*., 2012; Janjua *et al*., 2010).

Recent ranking by Maple croft of the UK, places Pakistan at 28th amongst those that will be most severely affected by Climate change (IUCN, 2009) while IPCC ranked Pakistan 10thsince agriculture will be severely affected due to changes in climate (Nurse *et al*., 2014).The agriculture sector in Pakistan plays a pivotal role since the income of over 47% country population is dependent on this sector (Oxfam and ADPC, 2014). It is projected that global temperatures will increase by 3°C by 2040 and 5°C to 6°C by the end of this century (Oxfam and ADPC, 2014).

Pakistan because of its geographical location in a heat surplus zone is highly vulnerable to climate change and agriculture being a climate sensitive subject is directly impacted by change (Nizami, *et al*. 2010).

Wheat being the staple food in Pakistan is the major focus of policymakers with respect to food security. Wheat grown in winter and harvested in summer is more vulnerable to climatic change ultimately leading to a threat to food security in Pakistan (Janjua *et al*., 2010). Further changes in temperature and rainfall during reproductive and vegetative stages are important factors in wheat production (Mitra & Bhatia, 2008; Semenov, 2009). Achieving goal of food security, especially for poor populations becomes difficult as a result of climate change (Gregory *et al*., 2005; Rosegrant & Cline, 2003) coupled with other problems, such as rising population, shortage in water availability and land degradation.

Some of the major issues arising from climate change include reduced water availability when most needed by the crops, increased incidence of pests due to temperature and humidity co-relation and overall yield losses at flowering or maturity stages due to extreme events. The CC is/will drastically reduce cereal production of wheat and rice as well as cotton and sugarcane. In southern Pakistan, yields of major cereals is predicted to decline by 15-20% according to regional climate models whereas in the northern areas, minor improvement is predicted in yield due to increased duration of growing period (MoE, 2009). Similarly, livestock production is predicted to decline by 20-30%, creating crises in milk, meat and poultry supplies and pushing prices beyond reach of the average consumer (MoE, 2009). Rangelands will be over-stressed from prolonged droughts and shifting human and livestock populations around riverine areas and in mountainous regions (MoE, 2009). In land fisheries is predicted to be reduced due to decreased water availability and increased water temperatures beyond thermal limits of certain species. Fruits, vegetables and horticultural products are high-value exports for Pakistan and will face challenges under the changing scenarios. As a result of all these issues, the livelihoods of farming communities will be affected at large and marginalized groups including women, children and the elderly will be negatively impacted through widespread malnutrition. Adapting to climate change can reduce negative impact on agricultural productivity (Di Falco & Chavas, 2009).

Due to the peculiar socio cultural and geo political scenario especially since 9/11, governance structure and security situation in FATA, the availability of credible data and research work remained a limitation. Now since climate change effects are appearing fast, farmers, various service providing departments, practitioners and decision makers feel the need to have proper baseline to establish facts for taking suitable measures for adaptation to climate change in FATA. The study of "Farmers Perception about Climate Change in Bajaur" is the first step in this direction which is conducted by the Climate Change Centre through the Soil and Environmental Sciences Department at the University of Agriculture Peshawar with support of the Livelihoods Programme Hindukush (LPH), Intercooperation.

The aim of this study was to record the experiences and perceptions of local farmers regarding climate change and its effects in FATA.

Objectives of the Study:

- Record farmers' perceptions about climate change.
- Document past and present cropping patterns and relationship with changing climate scenerio if any.
- Understand rainfall prevalance, distribution and changes in the surface and subsurface ground water.
- Learn farmers'adaptation and mitigation strategies if any in response to changes in temperature and rainfall events

Materials and methods

This study is based on qualitative method using focused group discussion with the help of a well-structured questionnaire (Annex 1). This questionnaire was based on the crops grown in the area during the last 20 years, changes in cropping pattern and sequences, changes in temperature and monsoon rainfall in the last 20 years, changes in dry spell and drought, water availability, both surface and subsurface, and any changes in the availability of drinking and irrigation water over time. The questionnaire was pretested with the farmers at the University research farm. The study however included quantitative aspects by including probing questions to determine certain changes in concrete terms. For example, a question was asked whether they have noticed any changes in the temperature or quantity of rainfall in the last 20 years. The response was noted in terms of yes or no. However in order to know the quantity of change, a follow up question was asked if the rise or fall of temperature is 1/4, 1/2, 3/4, part of a Rupee (i.e. percentage). Such quantities however are approximate and can only suggest the trend with low, medium or high intensity changes. In this way we can say that the study team applied both qualitative and quantitative means for recording farmers' perceptions.

The data were collected from Bajaur Agency in three UC (Table 1) including Tauheed Abad (Tehsil Utman Khel), UC Inayat Kalay (Tehsil Khar) and UC Raghagan (Tehsil Salarzai). The respondents in each UC comprised of farmers from different villages in the same UC with the age group from 40 to 80 years. An average recall period was 20

years within which they may have noted any changes in the climate. The UCs were identified keeping in view the strength of agriculture in area. A total of 10 to 15 farmers actively involved in agriculture from generations were selected for the FDG. The changes in the rainfall or temperature or overall agricultural practices were recorded on the basis of the response from majority of the group. One of the difficulties in asking the question was the clarity of the question. For example, definitions of winter or summer as these are remembered by the farmers by the names given in local language. In order to resolve the issue, the winter was defined as the time when the people start using blankets (locally call Brastan) and summer starts when one needs to turn on fan if there is electricity in the area. The spring was defined in the term of flowers coming out of the wild herbs and shrubs in the area whereas the autumn was defined in term of shedding of leaves by deciduous trees. The respondents were invited and gathered in a convenient place either in a nearby Hujra[1]or in farmer community center (Agriculture Extension Department building constructed for the purpose).

Table 1: Agency and the villages comprising respondent for FGD

Agency	Tehsil	Union Council	Villages
Bajaur	Khar	Inayat Kalay	Damadola, Choptra , Bajour, Bhai Cheena, Mamund, Tanai, Loye Mamund
Bajaur	Salarzai	Raghagan	Pashat, Tabai, Shah Narai, Raghagan, Salarzai, Bara Raghagan, Pasahat, Ziarat, Tandai, Dheraakai, Rasha Dheerai
Bajaur	Utman Khel	Tauheed Abad	Boondai, Shagai, Mirwas, Tauheed Abad, Rahmat Abad, Daman Shah, Ali Jan Kalley

The responses and the interpretation of results are mainly on the consensus answers that were further refined by taking the averages of all the three UC data of the concerned Agency. For example, the question regarding length of summer or winter in terms of early or late by weeks was received like 2-3, 3-4 or 4-5 etc. and was averaged and the fractions were adjusted as whole numbers.

Study area

Bajaur was declared Federally Administrated Tribal Agency in December 1973. Geographically, Bajaur Agency adjoins Malakand Agency on the South-East, Dir District on the North-West, Mohmand Agency on the South-West and Afghanistan on the North-West. Administratively, Bajaur Agency is divided into seven Tehsils including Barang, Nawagai, Khaar, Mamund, Salarzai, Utmankhel and Chamarkand whereas, Khaar is the headquarter of the Agency, located at a distance of about 140 km north of Peshawar connected through a metalled road via Mohmand agency and Malakand agency. The land mass of the Agency lies between 34^0 30′ and 34^0 58′ north latitudes and 71′ 11^0 and 71′ 48^0 east longitudes. The total geographical area of Bajaur agency is 1290 km^2 (government of FATA) comprising of hills, terrain and plain area. The area under forest is 21,515 (source: FATA Development Statistics 2012) but the forest area is being converted rapidly in to Agriculture land and for house construction mainly due to rapid population multiplication and settlement of Afghan refugees. The diffused boundaries between Pakistan and Afghanistan make some of the area as no man's land where there is indiscriminate cutting of forest trees. The total cultivated area of the agency is 75,350 ha, whereas the uncultivated area is 53,685 ha. Land under irrigation is around 14,061 ha (about 26%) and the remaining (74%) is un-irrigated (source: FATA Development Statistics 2012). Three – fourth of cultivated area is under Barani and under flood irrigation (especially during monsoon season)managed by farmers, without any support from public-sector. Water availability is from precipitation, surface and ground water. According to the 1998 census, the population was 595,227 (FATA, 1998) but recent estimates show that the population has grown to 0.942 million. Population density is 730 persons per km^2 being the highest in FATA agencies. Population growth rate is 4.33% per annum (Fata Capacity Building Programme, 2010).

Bajaur is known for its extreme climate. The winter season generally begins in November and lasts till the end of March. The winters are extremely cold and sometimes temperature plunges below freezing point. The mean maximum and minimum temperatures in these months are in the range of 5 to 16^0C. The summer season usually starts from May and last still October. June, July and August are the hottest months. The mean maximum and minimum temperatures in this period are in the range of 23 to 36^0C.Westerly disturbances contribute about 70% precipitation and rest by monsoonal disturbances. Bajaur Agency's mean annual rainfall varies from 350 to 500 mm with an average of 375 mm. ADB-FRDP, (2010) indicated mean annual rainfall of 738 mm with variation of 500 to 1000 mm. Wide variation in estimates for mean annual rainfall of 375 and 738 mm is a major constraint limiting sustainable management of water resources. (FATA Capacity Building Programme, 2010).

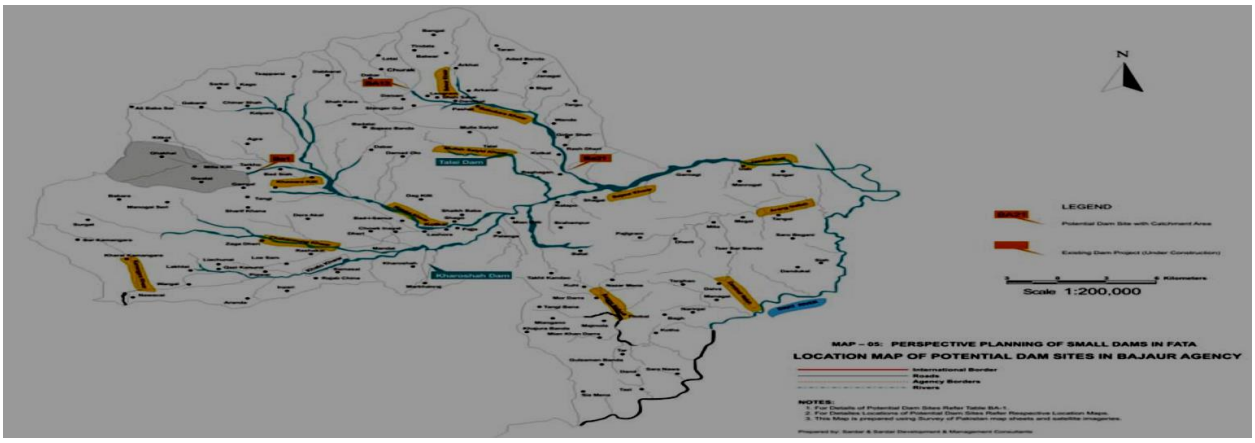

Figure 1. Map showing the administrative units and roads of Bajaur Agency

Results

Crop and livestock

The major winter crop is wheat, grown on 82% of cultivated area followed by brassica while barley is mainly grown as fodder on less than 10 percent area (Fig. 2). Brassica is grown on marginal lands, on the boundaries of field as well as a relay crop in the wheat. The major winter vegetables include garlic and onion for commercial purposes while green pea and coriander are also grown mainly for household requirements. The main summer crop is maize and about ¼of the area remains fallow because of unavailability of water. Rice is grown only on 1% plain area using local variety (Begamay). Major vegetables grown in area are tomato and chilies. Millet and sorghum are not grown anymore and the area allocated to these crops is cultivated with pulses including lentil and beans. Cows and goats are the major livestock with few sheep and buffalo. Poultry (mainly layers) are kept in almost every household as integral part of economy as well as a source of protein. Donkeys were kept in the past in every household mainly for transporting agricultural products from the field to the house or market and carrying water from distant places but these are very rare now. Few people are keeping horses for carrying goods and as a means of transportation but the trend is decreasing since relatively affordable non custom paid vehicles are available that serve the purpose.

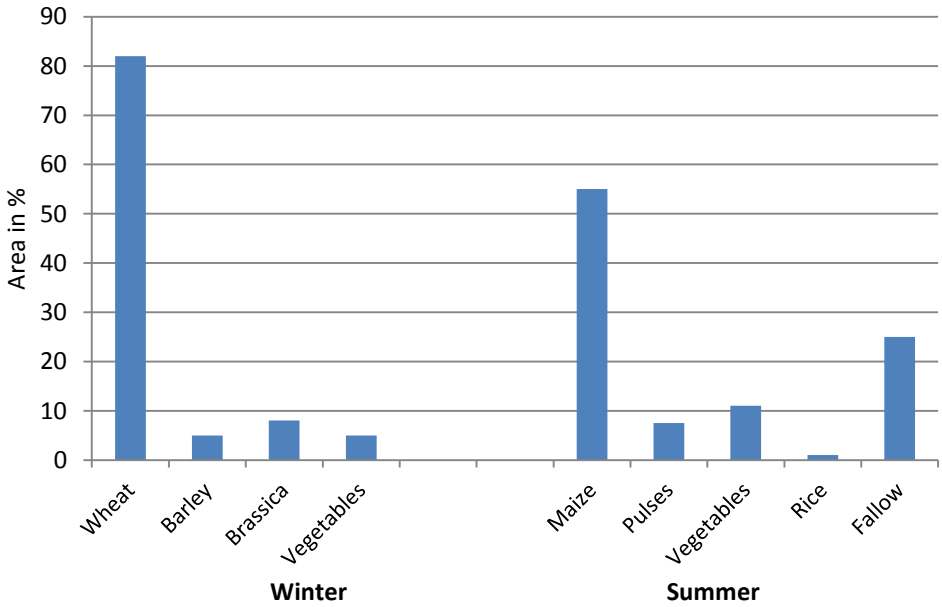

Figure 2. Winter and Summer cropping pattern and areas allocated to each crop in Bajaur

Environmental services

Major environmental services as stated by the respondents are water, firewood, medicinal plants, wildlife, tourism and minerals. The water is the prime environmental service as the respondents from time of their ancestors are dependent on rainfall and minor streams in the upper reaches for irrigation and recreation. Recently, a number of tube wells have been installed that meets the demand of irrigation and drinking purposes and the trend is increasing due to awareness of the community and their exposure to modern technologies. In the past, their existed the practice of water

harvesting, collecting water in ponds (Johar) on communal land for meeting the drinking water requirements of their animals, bathing, washing clothes and construction of houses which still exist but the people are not using it because every household now has access to clean drinking water supply).Due to education and awareness through print and electronic media, the people have realized that utilization of water harvested in ponds are non-hygienic and is the root cause of water born human diseases. Community has started establishing their own tube wells and dug wells which have minimized water shortage. However, these installations are drastically depleting the underground water resources as evident from the water table depth lowering by about 20 to 30 ft in area over the last 10 to 15 years.

Firewood (specific tree locally called Serhi) is a major source of energy for cooking and keeping their houses warm in winter. Other forest trees include *Zizyphus mauritiana* (ber), *Morus alba* toot), *Melia azedarach* (Bakain), *Eucalyptus camaldulensis* (eucalyptus) and *Populous* spp (poplar). *Dalbergia sissoo* (Shisham) also grow in the landscape there but the number is decreasing due to die back disease as was evident from shishams trees on road side. The furniture demand of the people of area is met using the trees produced within Bajaur area.

Different types of medicinal plant are naturally found in the area such as Mentha (mint), benosha, shatery, khwagawaly, kandar, kwarai, kashai, mamiekh pamankay, kagaa,manro,lada,manrho, Serhi and pergai (The scientific names are given in Appendix II). All these plants are used for various medicinal purposes for humans and livestock, and now their use is increasing day by day due to their popularity and demand.Wildlife including jackal, fox, monkey, rabbits and porcupines are becoming endangered and their numbers have noticeably declined when compared to the past. The commonly found birds are sparrow, partridge, and pigeons but now their number is also decreasing natural vegetation due to cutting of forest and conversion of forest land in to agriculture land, climatic conditions and increase in human population. Honey bee was the most common insect meeting the honey demand in the area and also as a vector for pollination. However, due to intensive use of agro-chemicals, the natural bees' population has decreased tremendously. Tourism was most common during the summer season because of comparatively cooler summer and good road infrastructure in the Agency. A fluctuating law and order situation has changed perception of potential visitors hence very few tourists are attracted to Bajaur. Mineral is another important resources in the area and the exploration of minerals such as copper, iron, chromite and marble may improve economic activity and generate employment provided the law and order situation gets better and the investors start excavation using modern technology. Good quality marble is available in different area such as Tahet, Inzary and Newagai.

Perception of community about change in temperature

The respondents unanimously suggested that they observed seasonal temperature changes during the last 20 years (Fig. 3). The rise in temperatures has been felt in the last couple of years and one of the arguments supporting their response was the disappearing of frost in winter that was one of the common features. Secondly, the people very rarely need to sit around the fire in winter to keep them warm. However, the summer temperature has decreased by about 20% in June- July and the decrease in temperature was attributed to reduction in hot blowing wind (locally called loo) in the afternoon during summer and more vegetations. Although the area under natural forest as well as forest trees species has been decreased tremendously due to conversion of forest land into agricultural land whereby the numbers of fruit trees as well as agriculture crop/tree species increased significantly. It was also noted that in the past, the wooden furniture used to heat up in the houses (locally call it "katuno baoor kawalo") but now such situation does not prevail due to more plantation in area while in the past, most of the area was barren. Spring temperature has increased by about 20% when compared to past temperature. Similarly the fall temperature has increased by about 10%.

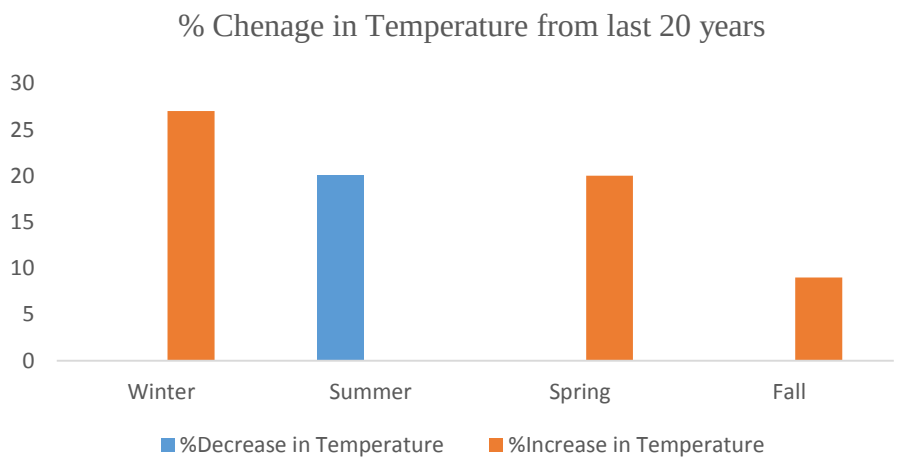

Figure 3. Percent change in temperature from last 20 years

Perception of community about change in annual precipitation

The respondents have observed significant changes in timing of monsoon during the last couple of years (Fig. 4). According to respondents, monsoon rains (Locally called Pashakal) in the past usually started in the middle or last week of July and continued till mid August. Now, there is a delay of about 4-5 weeks and the distribution and intensity have also changed. In some years, there is very little rain with very low intensity while in some instances, the distribution and intensity is very high causing damages to properties and humans (e.g. the event of 2010). Most of the respondents said that "*pashakaal baraan baadro ky shoroo shi*" (the rain of monsoon shifted from the month of July-August to August-September). Majority of the respondents were of the view that the overall quantity has increased by about 15% while the frequency and distribution have also changed i.e., it happens once or twice over the entire monsoon season. They supported their observation of increasing intensity by observing high flood in the swollen streams (khwar) that sweeps away houses and animals located on the banks. This has become a common feature now when compared to past. Respondents also observed changes in timing of winter rains over the last 20 year and mentioned that winter rains are delayed by 6-7 weeks. They supported their argument saying that in past winter rain would start just after germination of wheat crop but now it is delayed and the winter rain start late in January or February while current winter (2014-2015) was one of the driest winters over the last 20 years. Similarly, the overall quantity of winter rainfall has also decreased and noted a decrease of about20 to 25% (Fig. 5).

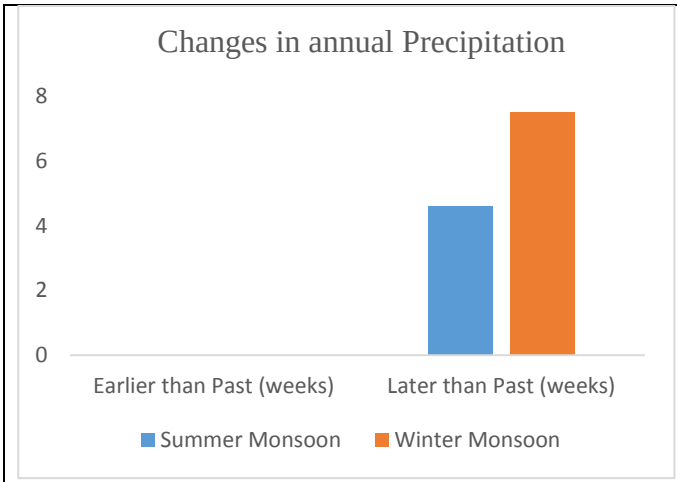

Figure 4. Perception of community about change in annual precipitation

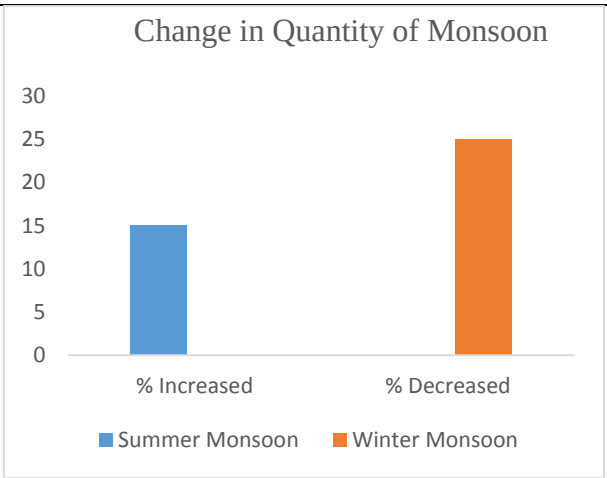

Figure 5. Perception of community about change in quantity on monsoon

Perception of the community about drought

Drought is a prolonged period of dry weather (due to lack of rain) that causes physiological stress in major winter (wheat) and summer (maize) crops. Respondents also observed changes in seasonal dry period during the last 20 years and noticed periodic dry spells (Fig. 6). In the past, the winter dry spells continued for over 3-4 weeks while presently, the winter dry period is significantly prolonged and is spread over 7-8 weeks. The respondents argued that there were low intensity rains for about 6 to 7 days in winter (locally they say "*pe jammee ki ba loe jarai va*" i.e. there used to be prolonged rain spells lasting for couple of days in winter) but now the winter rains are like monsoon rains i.e. high intensity with short spells. Accordingly, the respondents noticed very few (sometime 1 week) dry period in spring in past but now it is more than 2 weeks. The summer drought used to be3-4weeks in the past but now the duration of dry period hasincreased to 8-9 weeks. Autumn in the past was not dry but now it is sometimes completely dry particularly during the last 6 to 7 years. In order to support their argument regarding dry autumn and winter, they are affiliating throat and cold/flu diseases to prolong/dusty autumns and winters that pass without rain. Winters are almost dry (complete drought) for the last couple of years while the winter rains have shifted towards spring.

Perception of the community about length of season

The respondents observed variation in length of season and according to their observation, winter season lasted for about 13-14 weeks (15thNov-Feb) in the past. This has shrunk in their perception to 10-12 weeks (15 Dec-Feb) showing shorter winters (by 2-3 weeks) when compared to the past (Fig. 7). Delayed rains in winter are causing warm situation and hence farmers tend to believe that winters are now shorter. Similarly, spring and autumn have also shrunk and in some years, both autumn and spring are disappearing. Summer on the contrast is prolonged and almost more than half a year long and it is warmer and hotter. Length of summer varied from 13-16 weeks (May-15 Sept) in the past but nowadays summer almost start from15 April and last till October (26-27 weeks). Spring in the past was spread over the month of March and April (7-8 weeks) while currently; spring duration is reduced to 5-6 weeks (last week of February to 1st week of April). The respondents without having second opinion reported prolonged and hotter summer (this is contradictory to respondents' perception given in Fig. 1. They expressed that the overall summer temperature has

reduced however there are periods in summer where the temperature feels like 50^0 C) compared to the past. Duration of autumn in the past was around 5-6 weeks (15 Oct- Nov) while presently, the length of autumn has reduced to 3-4 weeks and in some years there is nearly no autumn at all.

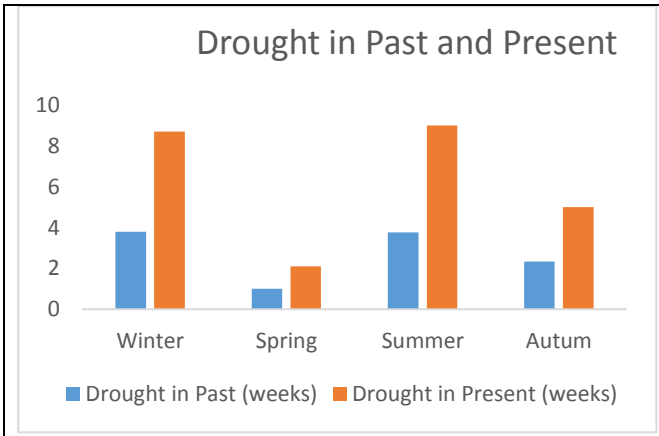

Figure 6. Perception of the community about drought

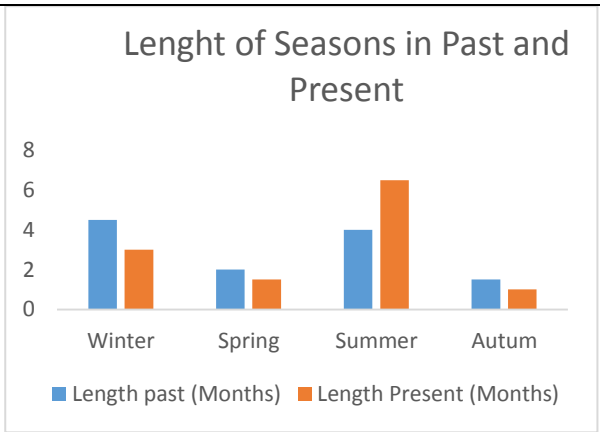

Figure 7. Perception of community about length of season

Community observation about the impact of climatic changes on animal productivity and crop yields

The respondents of different villages observed changes in the crop and livestock productivity and reported manifold increase in crop yield and animal production (both in numbers and milk quantity) when compared to the past. However, the changes in productivity of both crops and animals are not ascribed to the climate change. Rather the yield and milk production increases are attributed to improved technology (good seed, fertilizers, pesticides etc.) in crops and improved cow breeds, availability of modern and better nutritional food for livestock such as artificial wanda, kal (oil cake) and also improved fodders. Livestock in the past were only surviving on open grazing. Now farmers keep only one or two cows with 10 times more milk compared to local cow breed in the past. Similarly, the number of goat increased manifolds due to better breeds whereas the numbers of sheep have declined due to the reduced productivity of milk and wool as well as low reproductive capacity (only one per year). Farmers only keep male sheep for fattening and slaughtering on Eid festivals. About the number of buffalos, there were different views from the respondents of different villages. In UCs Arang and Inayat Kalay (Tehsil Khaar), the respondents indicated reduction in buffalos from 70 to 80% in favour of improved cow breeds with 10 time better milk production when compared to the past. In UC Raghagan however, the respondents reported that the number of buffalos remained the same or may be increased due to preference for buffalo milk which has more fats (kuch). This milk has more market demand.

The respondents observed significant changes in crop yield during the last 20 years. Wheat and maize yield increased almost 4to 7 times respectively when compared to past. The increase in yield was attributed to the introduction of new varieties, good quality seeds; use of chemical fertilizers as well was mechanized farming system along with using pesticides. The distribution of land with respect to acreage grown by each crop in the past and present is presented in Fig. 6. Rice was grown in the past in different villages of UC Arang (Tuheed Abad) and now the cultivation is reduced by about 90% or even not grown at all because of shortage of surface water supply, mainly natural springs. Springs were fed by rain water in the past which has been reduced now or those spring channels are dry. Tube well irrigation for rice is not economical although the tube wells have sufficient water pumping capacity. About barley and lentil, the respondents from all the villages viewed that its cultivation has decreased by 90-95% and 90-100% respectively because the production is low and not economical when compared to wheat and maize if grown on the same land.

Most of the respondents indicated that its cultivation and production of vegetables have increased when compared to the past. This trend stems from use of hybrid varieties, market demand as well as better prices to the farmers. The introduction of new technologies (especially tunnel farming and off season vegetable) may further bring more area under vegetable cultivation in the future. One of the significant changes has been noted in tomato. Farmers are growing tomato three times a year consecutively. In farmers' views, prolong summer makes it possible to get three crop harvested in a single year by growing first tomato crop in wheat during late March (tomato in standing wheat crop). Wheat is harvest in early May and by than the tomato crop is ready for picking. The 2nd crop is grown after wheat harvest and the third crop is grown in late September and still weather is hot enough to get the third crop ready for picking in late October or early November. In the past this was not possible at all (Fig. 8). This is an opportunity which climate change has brought to the farmers. Another significant change in crop rotation/sequence, though not related to climate change, is the elimination of opium cultivation because of restrictions on its cultivation by Govt. law enforcing agencies.

Comparing current and past seasonal crops

The respondents listed different winter crops which were grown 20 years ago:

Table 2: Major crops/vegetables 20 years ago and as of today

Season	Major crops 20 years ago	Major crops as of today
Winter	wheat, lentils, mustard, barley, opium	Wheat and vegetable (garlic, pea, onion)
Summer	maize, rice, millet/sorghum	Maize, and vegetable (chilies, cucumber and tomato)

The vegetables were grown in the past only on small piece of land as kitchen garden but now most of these vegetables especially chilies, tomato and cucumber are the major cash crops of summer vegetables. Rice cultivation is reduced in some villages such as UC Tauheeabad and still is cultivated in plain areas of Inayat Kalay, Tehsils Khaar, Raghagan UC Tabai and the acreage lying fallow has reduced compared to the past.

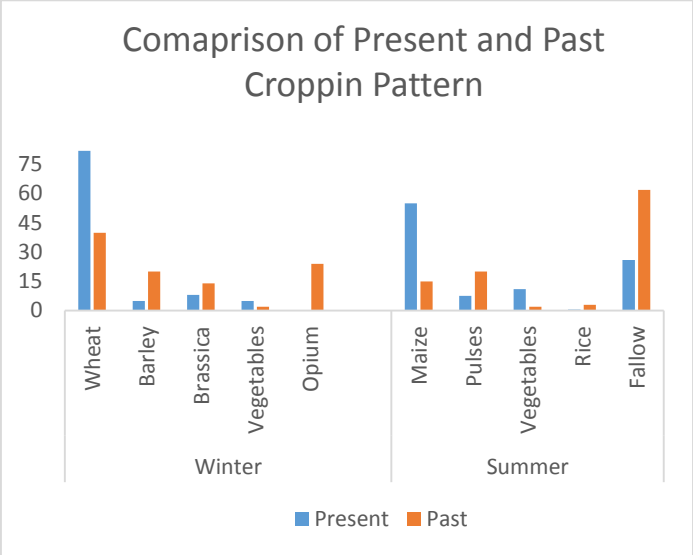

Figure 8. Comparing current and past seasonal crops

Adaptation to climate change

Introduction of new varieties

The respondents stated that they have introduced new hybrid seeds which are slightly heat and drought resistant. This is however, the case of adjustment in sowing time such as introduction of early and late tomato varieties and not resistant to heat or drought in true sense. Efficient utilization of available water has helped bringing more areas under cultivation and enhancing yield. At the same time introduction of early maturing varieties has helped in securing crop yields. The respondents stated that they soak seeds in case of drought in order to help the seed germinate until it rains or the tube well water becomes available for irrigation. The respondents also stated that they practice water harvesting techniques in the field. Terraces and contour farming was also observed in the surrounding vicinity.

Change in sowing time

The respondents stated that due to shifting winter rainfall pattern over the years, they have made some adjustment into the sowing time of crops. They have introduced late sowing crop/vegetable varieties that were not practiced 20 years ago. Further, the respondents also stated that some of the farmers have also started tunnel farming. This practice may be extended in future by other farmers with respect to scale of production depending on farmer expertise, availability of hybrid varieties, fertilizers and market forces. Few of the progressive farmers are practicing the tunnel farming for off-season vegetable production of tomato, cucumber, squash and chilies. Tunnel farming technology has reached Bajaur as a result of widespread practice in Swat and adjoining areas where former Swiss horticulture project operated by Intercooperation operated from 1987 to 2004.

Change in weeding practices

Regarding the application of pesticides, the respondents stated that they are mostly using weedicides instead of cultural practices of weeds control and in their opinion the results are very effective. Excess weeds, therefore, is no more seen as a problem by the farmers in the crops.

Changes in irrigation practices

The irrigation infrastructure has completely changed when compare to the past and now majority of the farmers have their private tube wells and have lined watercourse at field level. The respondents noticed that 20 years ago, they were dependent on rains for crop cultivation and now supplemental irrigation water is available that changed the cropping pattern/sequence and resulted in introduction of new crop vegetables and elimination of few (e.g. opium, rice). The change in cropping pattern and productivity was made possible due to the electrification of several areas in the Agency that made the installation of tubewell possible. However, currently due to frequent power breaks and electricity shortfall, most of the farmers have their private generators run by diesel/petrol thus irrigating crops is not an issue whenever need arises. This may however have economic repercussions for the farmers since cost of irrigating fields' rises with use of generators.

Change in fertilizer application

The respondents stated that they are more aware of the importance of fertilizers when compared to the past. In past they only applied farm yard manure as a sole source of crop nutrition whereas now they apply major nutrient fertilizers in optimal amounts in split dosage and in recommended quantities and this was possible because of improvement in agricultural extension department services that were existing in the past but were not as active as they are now.

Other changes

The respondents stated that their standard of lives has improved compared to the past as investment in agriculture give better return provided they have resources and natural disasters like flood or hailstorm does not damage their crop. Most of the responded are having access to the print and electronic media and improvement in literacy rate is visible when compared to the past. The establishment of Agriculture Bank has facilitated getting loan for purchasing tractors, fertilizers, seeds etc. in addition to availability of loans for purchasing cows and buffalos. However, small farmers (having small land holding) are still at risk and are not benefitted from the improvement in innovations in agriculture sector (in term of loan from bank, fertilizers, hybrid seed etc and installation of tubewell) as compared to the few landlords and progressive farmers. They farmers stated that now they are able to grow many crops, fruits, vegetables in their own fields whereas some of the progressive farmers (about 20% of the respondents) also added that they are also practicing value addition including preparation of jams, marmalades and preserve tomato, okra and bringles at home which they have learnt in the trainings being provided to them by various government and non-government organizations (NGOs) in the area. They also argued comparing with the past, that milk production has increased manifold and now they are also able to sell milk in local market.

Changes in land holdings

Although the individual land ownership has decreased due to land fragmentation with population increase but the overall land under agriculture has increased when compared to the past. New land has been brought under cultivation and there are very few or no fallow lands. The respondents claimed about 75% increase in agricultural land has been achieved in the area and that was mainly possible due to installation of tube well to supplement irrigation demand as and when needed. In the long run however, groundwater depletion may reverse the situation and therefore needs to be carefully looked at in the adaptation strategies.

Water Availability

As stated earlier, the respondents are happy to report that water for irrigation in both summer and winter increased manifolds (more than 50%) due to installation of tube wells that resulted in changes in cropping pattern as well as in yield. Now water is available for both irrigation and drinking as and when needed (Fig 9). Moreover, the level of groundwater has depleted noticeably as result of poor relationship between the natural balance of recharge, water demand and pumping of water. Community in the past were taking water from dugwells only for drinking purposes and the groundwater table was shallow (10 to 15 meters) in most of the area. Installation of both public and private tube wells has led to depletion of water table in many parts of the Agency and the water table depletion is significant ranging from 6 meters (20 ft) in plain areas to about 9 meters (30 ft) in areas having rolling topography. Water is being pumped much more than natural recharge of groundwater. The recharge of the ground water is mainly through the monsoon rains and since the rains have been reported to have intensified in short duration, there is little time for water to percolate and keep with the required pace of recharge and balance the equation of water pumped out. The respondents stated that the availability of drinking water has increased by a scale of more than 85%. They justified their statement with the facts that in past there used to be open ponds (Johar/Jowar) which were the only source of water for drinking and domestic purposes. Then the community developed dug wells which were also very limited and now each family has its own private well at home for drinking and domestic water.

The reason for increase in tube well irrigation is exposure to new technologies, electrification of the Agency and the better economic conditions of big farmers in the area. In winter due to low demand for agriculture and drinking

purposes, the availability of water has increased by more than 85%. They have also noticed water table rise during relatively cooler months that may be due to less demand and low intensity rainfall in the area that results in low runoff and more recharge when compared to summer rainfall.

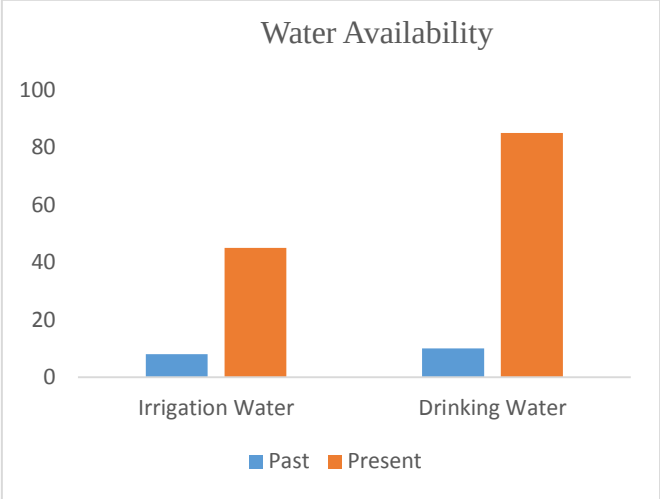

Figure 9. Perception of the community about the water availability

Conclusion

Wheat and maize are the dominant winter and summer crops respectively. Opium is completely eliminated from the system and vegetables cultivation is common for commercial purposes when compared to the past. The fallow land has significantly reduced in terms of acreage and this was possible due to installation of public and private tube wells. The crop yields have increased several folds when compared to the past and that happened due to introduction of improved crop varieties, fertilizer applications and following mechanized farming. Increasing temperatures in autumn, winter and spring are reported whereas interestingly, the summer temperatures are felt slightly lowering down with a declining trend. There was a little disagreement among the respondents about the spring temperature as they were of the opinion that spring is hotter if there were no rains but if there are rains, spring feels like extended winter. Majority were of the view that spring is either embedded in the winter or merged into the summer. Summer is prolonged in whereas all the other three seasons have shortened. The autumn has shifted toward winter or merged with winter in some of the wet years while during dry years, autumn also feels like summer. Spring season has reduced significantly.

The overall perception about the rainfall was that there are notable changes in rainfall distribution and its intensity over the years. Summer rains are delayed by about more than a months and intensity is very high and sometimes flashfloods occur due to intensive rainfalls. The autumn is mostly dry while winter rains have increased in quantity but delayed by more than two months as experienced during the last 20 years.
The availability of water for both drinking and irrigation has increased and that was possible due to installation of tube wells, both public and private. The water depth depletion was commonly observed and the farmers recorded about 20 to 30 ft underground water depletion. The rate of water pumping is mismatched with recharge and there is a likelihood of further decline if the mushrooming of tube wells continued and farmers did not change their behavior in pumping out water.

Keeping cows for milk production is becoming common in followed by goats while number of sheep is decreasing. The reasons of reduction in numbers are being its diseases and slow rate of multiplication compared to goats. Donkeys were kept mainly for transporting agricultural goods and these are now carried by vehicle. Thus number of donkeys has reduced tremendously. Similarly, number of buffalos is decreasing because improved breeds of cows' gives more milk with less care and low fodder intake.

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Watershed management for profitable use of land resources in pothowar

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Abstract

Conservation agriculture is becoming the hot spot technology of the agriculture and the conservation of natural resources (soil and water) is necessary to overcome the emerging problem of food security for the ever increasing population. The agriculture in Barani area (rainfed) especially in Potohwar is confronted with two main problems i.e., soil erosion and water stress. Soil and water are critical natural resources that sustain human life and the lives of all other creatures. Sustainable use of these precious resources is imperative to socially, economically and ecologically viable communities. The problem is further accentuated with uncertain behavior of rainfall. Keeping in view the specific Agro-climatic zones of these area loose stone structures were installed to control soil erosion and profitable use of rain water at different sites of Chakwal (Balkasar, Mangan, Dhok ber, Nain sukh). In addition to lose stone structures micro catchments and other moisture conservation techniques like addition of gypsum and incorporation of green manures were also introduced and adopted for cultivation of olive along with the crops on marginal land. Installed lose stone structure not only control the water and soil erosion but also enhanced the yield of wheat crop up to 16 - 36% in selected sites. In evaluation of these technologies through independent assessment survey conducted by NARC and ICARDA, it was concluded that these technologies pay back their cost to farmers within 3.5 years. SWAT model analysis is also being carried out for the out scaling of these technologies.

Key words: Rainfed; Water erosion; Moisture stress; Water harvesting; Green manuring

Introduction

Total geographical area of Pakistan is 79.61 mha. Area under cultivation is 21.59 mha; of which, only 5.34 mha (i.e., 25%) is free from soil limitations and is fit for intensive agriculture (Mian and Mirza, 1993). The remaining agricultural lands have various types of problems including formation of slow permeability, water logging, salinity and sodicity and wind and water erosion (Ahmed *et al*., 1998). Almost 15.9 mha of land 20% of total) is affected by soil erosion. Out of this, 11.2 mha is affected by water erosion (Ashraf *et al*., 2000). In Pakistan about 17% of the cultivated area is rainfed and depends on rainfall for crop production. Soil erosion is the process of detachment and transport of soil particles caused by water and wind (Morgan, 1995). Soil erosion by water and wind leads to decline in soil fertility, brings on a series of negative impacts of land degradation and other environmental problems, and creates a threat to sustainable agricultural production and environmental quality.

Water is a key element in the socio-economic development of any country. The increased population, urbanization, industrialization and agricultural activities however, widened the gap between water demand and supply. The water shortfall that was 11% in 2004 will increase to 31% by 2025 (GOP, 2001). The per capita water availability which was about 5600 m in 1947 has now reduced to about 1000 m – converting the country to a water-scarce condition. Due to this shortage of water and increase in population, there will be food shortfall of about 70 million tons by 2025 (ADB, 2002).

The dryland farming is practiced on about 12 Mha that constitutes 40% of the culturable areas of the country. However, it contributes less than 10% to the total crop production. The agriculture in Barani area (rainfed) is confronted with two main problems i.e., Soil erosion and Water stress. The average yields of major crops in these areas are far lower than their achievable potentials. The major reasons for this low agricultural productivity are: (i) low and erratic rainfall, causing stress at critical growth stages, (ii) soil erosion, resulting in loss of water and fertile topsoil. Out of a total geographical area of 80 million hectares (Mha), about 16 Mha are exposed to soil erosion of which 11 Mha are affected by water erosion, (iii) poor use of land and water resources due to small and fragmented land holdings and (iv) low agricultural inputs (Ashraf *et al*. 2007). Water is one of the most important limiting factors in the agricultural production of rainfed areas. The rainfall in these areas varies from less than 200 mm to over 1000 mm, 70% of which occurs during the summer months of July–September (Ashraf *et al*., 1999). Due to high intensity, short duration rainfalls and lack of watershed management and rainwater harvesting activities, this precious water is lost as surface runoff. This is not only the loss of water but also results in loss of fertile topsoil. There is a need to harvest as much as of this currently lost water as possible either on the surface or underground. Stored water can be used as supplemental irrigation to act as a buffer against crop failure during dry seasons.

The government of Pakistan is spending millions of rupees by providing bulldozers to the farmers at subsidized rates for leveling of gullied and eroded lands in rainfed areas of Pothowar Tract. Minor land leveling is of course, helpful for even distribution of rainfall water in the fields but major leveling work takes hundreds of hours to level gullies with the involvement of huge expenditure and during the process of leveling, top fertile land is buried while bedrock is brought on the surface where no crop can be grown successfully for many succeeding years. On the other hand, the soil becomes more prone to soil and water erosion. It is therefore always better to use this natural resource as it exists in the nature by adopting some other sustainable means and measures. This region possesses a large area under gullies and eroded lands which remains un-cultivated throughout the year. It is much needed to use these eroded lands in profitable way because it is always better to use the lands as it exists in the nature (Li et. al. 2000). Shortage of soil moisture in the dry rainfed areas occurs during the most sensitive growth stages (flowering and fruit filling). Supplemental irrigation can, using a limited amount of water if applied during critical crop growth stages, results in substantial improvement in yield and water productivity (Oweis and Hachum, 2006). The methodologies to enhance water productivity and limited water supply are: (a) supplemental irrigation for efficient use of the scares water in rainfed areas, and (b) water harvesting to ensure the sufficient water supply (Oweis and Hachum, 2003).

Gypsum ($CaSO_4$. $2H_2O$) is generally used to reclaim sodic soils and waters. Application of gypsum improves the structure and hydrologic properties of clayey or sodic soils. Gypsum used for agriculture purposes contains 23.28% calcium, 2.34% hydrogen, 18.62% sulfur, and 55.76% oxygen. The use of gypsum has also shown good results in conserving soil moisture under rainfed conditions and its use increases the infiltration rates and the crops yield (Chartres *et al*. 1985; Farina *et al*. 2000; Yu *et al*. 2003; Hamza and Anderson 2004; Rashid *et al*. 2008). Although the solubility of gypsum is very low, generally less than 1%, yet its benefits in conserving soil moisture can last for longer period of time. The use of gypsum has several other advantages such as:
It improves physical conditions of the soil
It improves infiltration rate of the soil
It increases wheat and groundnut yield from 15-20%.

Crop production under dry land farming condition depends upon rainfall which is limited and seasonal in these areas. The best agricultural management practice in these areas would be increasing the water conservation and ability of soil to store the available water (Mosavi, 2009). For this it is indispensable to improve the soil structure, infiltration rate and water holding capability of soil (Martens and Franken 1992). Aggregate of soil are the basic units of soil structure and organic residues application have been revealed for improve structure (Caravaca, 2001). Soil loosening decreases bulk density while compaction increases it. On compacted soils, the deep ploughing improved air permeability and soil water diffusibility (Majid, 1986). The loss of soil through runoff is occurred by high intensity of rainfall, low vegetation and low organic matter of the soil. It is also reported that soil loss is nearly proportional to exposed ground cover. Inadequate vegetation cover provided by rainfed crops causes serious problem of soil erosion, excessive runoff, flash-floods, formation of gullies and overall deterioration in quality, fertility and productivity of land gullies. The plantation of suitable multi-purpose trees and perennial forage and commercial grasses may provide the much needed protective cover to such degraded lands (Grewal, 1992).

Cover crop referred to any crop planted for providing the living cover on ground. They served as best management practices to overcome the problems of soil erosion, leaching of nutrients, weed suppression and improving the fertility status of the soil (Dabney *et al*., 2001). Green Manuring practice referred to incorporation of cover crop in soil in order to improve the soil fertility in addition to improving the physical properties of soil (Sullivan, 2003). A number of crops such as cowpea, Guar, Sesbenia can be used as green manure. Data showed that there is an increase of 9 % in infiltration rate by green manure incorporation in soil as compared to control treatment (Mosavi *et al*., 2012). It showed that more water contents are available in soil for crop growth. Cowpea green manure has been found to be most economical and effective in improving the infiltration rate and wheat yield from 15- 20 % (SAWCRI Annual report 2011-12, unpublished).
Green manuring also helps improve physical conditions and nutrients level in the soil. Plant materials in green/fresh grown in the field and later on incorporated into the soil is known as green manure. It helps to: (i) increase soil fertility (ii) improve soil-physical properties making it suitable for soil moisture conservation (iii) increase the crop yield (iv) keep the land covered during monsoon and helps to reduce the risk of soil erosion.

Materials and methods

For moisture conservation and erosion control, low cost water disposal outlets were introduced by the Soil and Water Conservation Research Institute (SAWCRI), Chakwal. The technology was initially tested at two sites i.e. Dammal and Khabbal during 2002. Seven structures were constructed at Damal and 12 at Khabbal before monsoon. The rainfall pattern at Chakwal is given in Fig. 1.

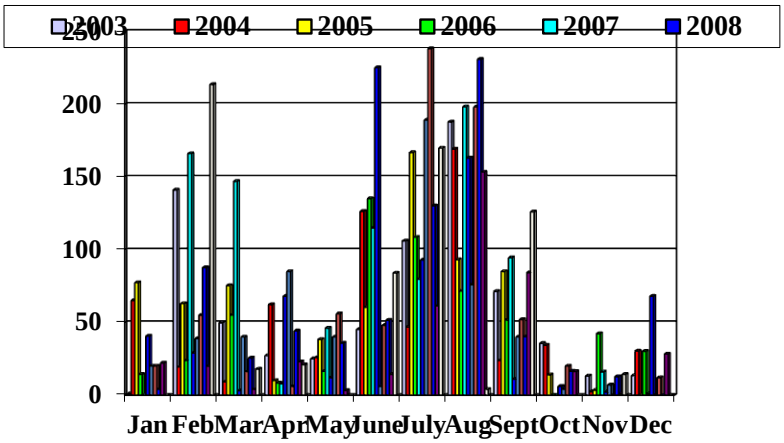

Figure 1. Rainfall pattern at Chakwal

The different land and water saving techniques (gully plugging, check dam, installation of loose stone structures, use of gypsum and green manure) are being used to reduce soil and water loss and the stored water is being utilized through efficient irrigation systems (drip & bubbler) to grow high value crops (fruits, vegetable and fodder) which increased farmers' return.

Results and discussion

Different land and management practices like gully plugging, check dam, installation of loose stone structures, use of gypsum and green manure are being practiced to conserve soil and water. The rainwater is being harvested *in situ* through loose stone structures, micro-catchments and rooftop rainwater harvesting techniques (Fig. 3 to 6 illustrates the whole story). The stored water, either in pond or tank or tanki (from rooftop) is used through different efficient irrigation methods like drip & bubbler under gravitational force reducing cost of energy, labor and time for growing high value crops.

The farmers were fully convinced after observing the performance for at least one rainy season. According to farmers' opinions, they were facing problem of erosion at these sites and such structures were much needed to control erosion and conserve moisture. The assessment survey results depicted that these structures had fully resolved the erosion problem. Not only the host farmers but also the fellow farmers' interest was reported high, as most of the fellow farmers had demanded these structures. Farmers were convinced that grasses and weeds have the capacity to work as a binding force just like cement and were of the view that with the growth in grasses overtime their strength would increase further. The grass growth was observed after about 6 months. Positive impact of these structures was also noticed in terms of soil/fertility conservation and less soil sedimentation in the downstream.

It has been proven that green manuring with cowpea during Kharif season, specified for wheat during Rabi, increased wheat grain yield up to 10-19 % in rainfed tract. There is also an increase of about 37 % in number of tillers as compared to the control treatment. The technology has also yielded promising results regarding the cost to benefit ratio which is 1: 1.45 in green manuring as compared to 1: 1.35 in farmer practice (Annual Report 2011-12, SAWCRI, unpublished). The crop cover treatments significantly reduced both runoff and soil loss. As compared to 35% per cent mean runoff from the bare plots, crop cover treatments yielded only 19 per cent. Cropped treatments responded differently in checking runoff as the different crops developed variable leaf area index during the growth period. Mean soil loss under bare and cropped treatments was 20.2 and 6.7 t ha-1 respectively (Khera and Kukal, 1994).

Long-term field experiments also revealed that application of 2.5 ton gypsum/ha is beneficial for crop especially wheat in rainfed areas that increases crop yield up to 15-25%. It also helps to conserve soil moisture which results in better nutrient uptake and hence the yield. This increase is mainly due to the improvement in the soil physical properties in response to gypsum application (Veeramani *et al*., 2012). It has been been observed that the application of gypsum not only helps in improving the yield of groundnut but it also improves the protein contents, plant potassium and phosphorus concentrations.

Figure 2. Erosion problem caused by rainwater in Pothowar

Figure 3a. Gully management through check dams and sediment deposition

The Check damming helped in reducing the soil loss and it is helpful in converting unproductive lands to cultivated ones.

Figure3b: Breaching of contour bunds results in reduced moisture for crops & educed soil productivity

Figure 4. Installation of loose stone structure and its positive impact on moisture retention and crop

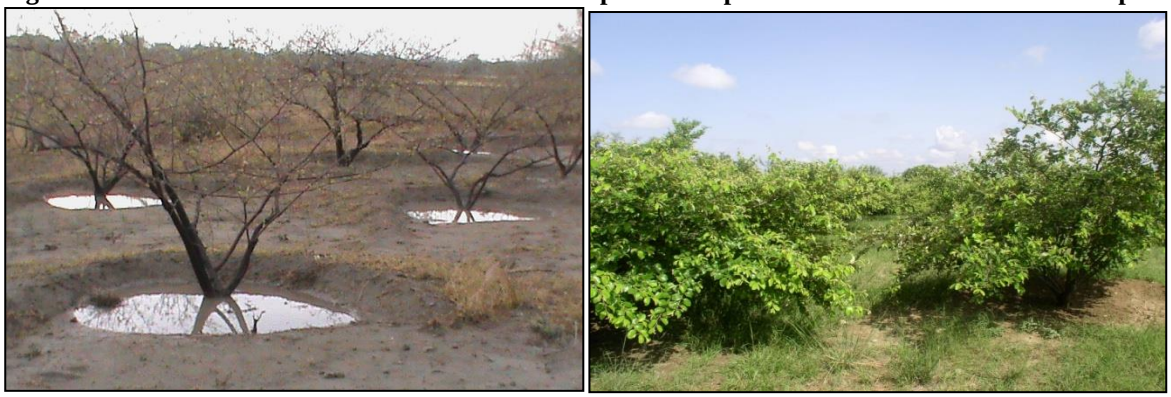

Figure 5a. Effect of rainwater harvesting through micro-catchments on plant health

Figure 5b. Effect of rainwater harvesting through micro-catchments on plant health

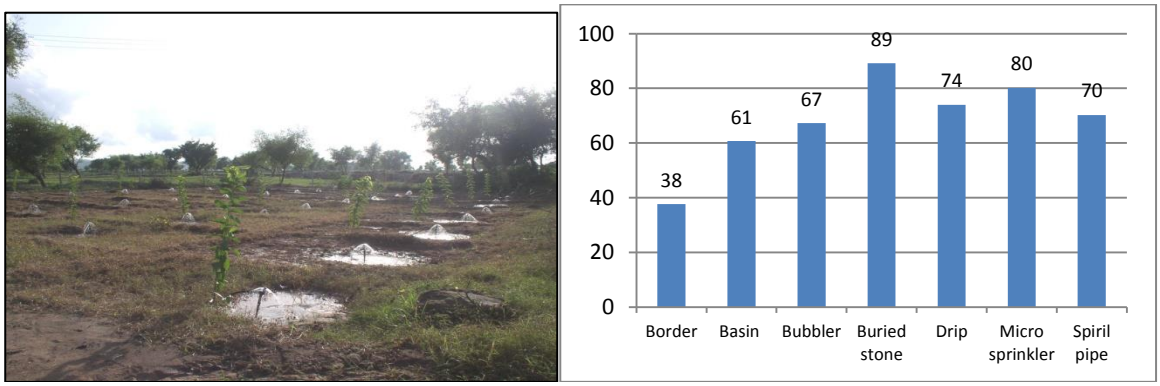

Figure 6. Efficient irrigation systems and % Water saving with respect to flood irrigation

Conclusion

In the past, many soil conservation measures including installation of cemented erosion control structures were built in then study area. However, these structures are much costly compared to the intervention under discussion. There is a clear need to identify low cost technologies similar to the one undertaken in this study. Such technologies should be evolved through integration of the local knowledge using locally available material with dissemination of the profitability results to a potentially large scale application. Lot of water is saved through these techniques along with reduction in soil loss through erosion, which resulted in increased in water & crop productivity and hence the farmers' income and living standard.

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Efficient use of soil, water and inputs is indispensable for sustainable agriculture under changing environments

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Abstract

Growth in agricultural productivity faces sever constraints due to land degradation, climate change, scarce water supplies, lack of quality seeds, unbalanced use of nutrients, use of obsolete traditional practices, confining to conventional cropping system, limited credit availability for the farmers, marketing system and competition for energy resources among agriculture, industry and urbanization. All these aspects demand serious attention of scientists as well as by the policy makers. Meeting demands for increased crop production in Pakistan is a great challenge. There is need to enhanced agricultural productivity with less inputs for ever increasing population of Pakistan but also improvement in produce quality while reducing adverse impact of agricultural practices on natural resources and the environment. Anticipating climate change and adjusting the agricultural practices and technologies is a major factor that can assure sustainable agriculture for future generations. Furthermore, the key to get maximum agriculture production with minimum inputs are resides in advancing research and transforming it into adoptable technology. For instance, achievement of higher yield coupled with efficient resource utilization (Fertilizers/ water/ seed etc.) may be possible by combining genetic and genomic resources with existing physiological and biochemical knowledge. Multidisciplinary approaches involving effective use of water, integrated and balanced use of bio-organo-mineral fertilizers, integrated pest management, reduced post-harvest loss techniques, risk management strategies, best agronomic practices, precision agriculture and use of GIS system and effective national policies for credit and marketing systems could be helpful in achieving the needs of food, fodder, fuel and fiber for the growing population. Efficient use of soil, water and inputs is indispensable for sustainable agriculture under changing environments to achieve the food security for our future generations.

Key words: Soil; water; sustainable agriculture; fertilizers; organic amendments

Introduction

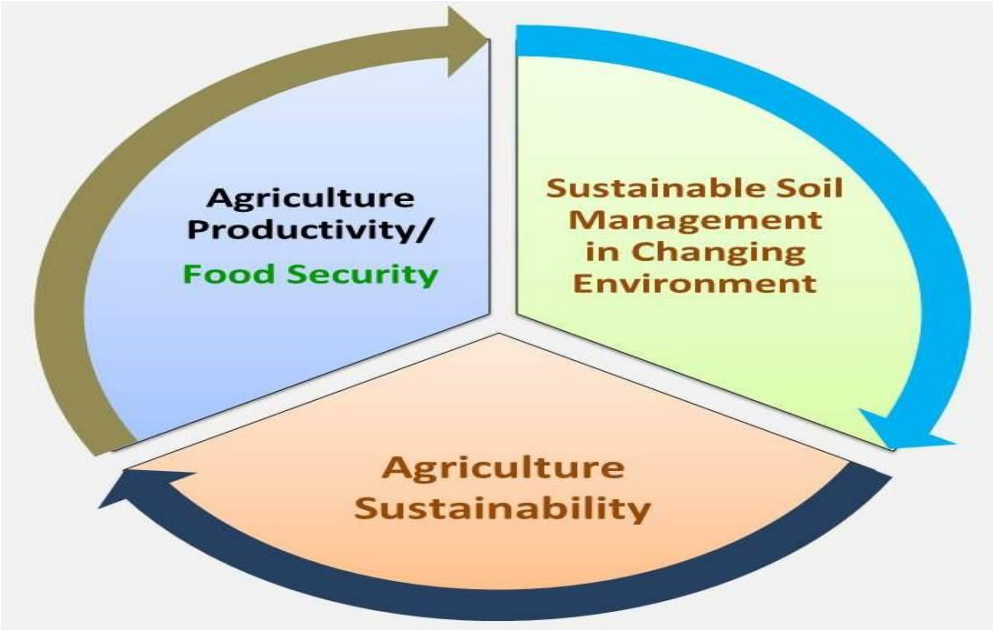
How Agricultural Productivity could be enhanced on sustainable basis to ensure food security for ever increasing population without disturbing the ecosystem in a changing environment? Population of the world is continuously increasing and by the year 2050 it is estimated to cross 9 billion (Intergovernmental Channel on Climate Change, 2007). This increasing population will require more food, fiber which will put greater pressure on agriculture for future food security. In developing countries this situation will worsen as the net cereal deficit of these countries is too much low. To meet the demands of food and fiber, the introduction of high yielding varieties and efficient fertilizers in agriculture has become a necessity of present time. Due to doubling of world population from 3 to 6 billion, a greater pressure is on agriculture sector. Increasing the agricultural production by at least 25% while maintaining prices at lower and sustainable level is the challenge of the hour. But at the same time increasing agricultural productivity may lead to greater environmental challenges. Agricultural sustainability greatly relies on the maintenance and availability of resources such as forests, water, nutrients and pastures (DFID, 2002).

At present, the use of high yielding varieties and fertilizers is causing depletion of nutrients, water and as well as causing pollution and land degrading on a massive scale. Although there are numerous challenges but our main emphasis is global food demand which is expected to double in next 50 years (Tilman *et al.*, 2002) and even now there are more than 800 million people facing hunger and have little access to food. So, when we are looking at the future, the big question in front of us "is it possible to meet such a large food demand without any deteriorating the environment. Agriculture is major source of income for majority of rural peoples in developing countries. According to past contribution of agriculture in food security and economic development improvements in agriculture sector is necessary to achieve success in our goal.

Agriculture sustainability

During mid of 20th century, increasing food demand due to increasing population led to advancement in agricultural technologies. These advancements in agriculture sector prevented a major food shortage and avoided the human population from so-called Malthusian trap. But debates on agriculture and resource management started in the 1950s and ultimately in the 1980s, the Commission on Environment and Development which is chaired by Oro Harlem

Brundtland, published an article "Our Common Future". The article clearly highlights the control of poverty, natural resource management and the sustaining of the environment (World Commission on Environment and Development, 1987). As a result of this publication, "sustainable development" was defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". This concept of sustainable development defines both the path and limits of growth.



Figre 1. Today's challenge to for sustainable agriculture

Sustainable agriculture emphasizes on developing technologies and strategies that minimize the dependence on environmentally harmful and nonrenewable inputs. Some examples of these sustainable solutions are organic permaculture, eco-agriculture, ecological and community-based, biodynamic, low-input, environmentally sensitive, farm fresh approaches (Pretty, 2003, 2002; Cernea, 1991; DFID, 2002). In order to popularize sustainable agriculture, strategies must be simple and productive with emphasis on management of natural resources (DFID, 2002). Policies for promotion of food production from limited resources efficiently, will encourage smaller farmers as well as take a positive step toward future food security. Continuous and wide scale adoption of this system will help to manage the limited and nonrenewable natural resources.

Agriculture productivity for food security

Agriculture productivity has a great impact on the economy of a country and it is an important pillar of industrial development (Adelman and Morris, 1988). Development in agriculture provides resources to other sectors of the economy (Krueger and Stern, 1989). The countries with higher agricultural productivity and growth were successful industrializers and economically stronger in contrast to countries having lower levels of agricultural productivity growth due to stringent trade and pricing policies have weaker economies (Coelli and Rao, 2005; Weibe *et al.,* 2000; Bravo-Ortega and Lederman, 2004; and Ludena *et al.,* 2007). This has important implications for food security, agricultural productivity and poverty reduction in low income countries, because the countries with lower R & D investment are those that have agricultural land constraints and low net food imports. Due to minuscule investment in R & D in these countries, they hinder their ability to generate modem technologies and enhance efficiency in the agricultural sector. For poverty alleviation and future food security governments should implement economic policies that promote agricultural productivity. These policies should be included within an agricultural development framework that helps transfer technology, increase efficiency, implement best agricultural practices and provides access to credit, inputs such as fertilizer and chemicals and market opportunities as well. Thus, through agriculture productivity improvement in economic status is possible.

Food security is defined as a state when "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1995). Sincere efforts are required to increase agriculture production in order to attain food security for increasing world population over the next half century. Investment in agriculture, nutrition and rural employment will boost income and ensure global food security. Experts suggest that the economic benefits obtained through agriculture are twice as effective in reducing poverty as compared to all other approaches (Crosson and Anderson, 1995). Food

availability is "production minus the sum of export and import". Even though, food production strongly influences food availability and security, however, the relationship is complex and many different factors are involved (Sen, 1994; Dreze et aI., 1995; Bowbrick, 1986). Presently, diminishing land productivity, water scarcity, low yielding verities, higher prices of fertilizers, poverty, higher food prices are most common factors hindering food security (World Bank, 2012). Malnutrition and poverty are most important factors which threaten the millions of peoples in developing countries. Unsustainability in agriculture degrades natural resources and makes it difficult to meet future food demand as well.

Major pillars of sustainable agriculture for agricultural productivity & food security

The increase in agricultural productivity in various countries and consequential poverty reduction over the last few decades is a product of the adoption of new technologies. Agriculture sector meets the food demands of a growing population, provides materials for the industrial sector and employs a larger proportion of the labor force (Pakistan Economic Survey, 2006-07). There is a need to enhance the agricultural productivity through the introduction of high-yielding crop varieties, balanced fertilizer, efficient pesticides and sufficient water for irrigation (Guha-Khasnobis, 2003). Yields of agricultural crops in Pakistan are still quite low compared to developed countries. Technology raises agricultural productivity; it should be the major factor in creating these positive effects (Thirtle *et al*, 2003). Besides agriculture, no other sector offers the equal potential to create employment and lift people out of poverty.

Strategies to improve soil health

Soil health is the major for scientists and researcher for sustainable agriculture for the future generation. Soil health has recently gained attention as soil degradation from high cropping intensity, lack of organic matter additions and mechanization have reduced yield potential. Intensive agriculture leads to increased erosion, soil compaction, greater pest problems, and reduced crop output (Kendrick, 1961). Soil degradation is a common problem in many areas of the world. Higher disease and pest pressure, soil compaction, decreased infiltration rate, reduced water holding capacity, low organic matter content and excessive runoff and erosion are common symptoms of poor soil health (Oguchi, 2004). By green manuring, addition of organic matter, biochar and balance nutrition, the soil health related problems can be solved. Efficient use of soil e.g., producing more with minimum soil degradation is need of time. Some strategies to minimize soil degradation are mentioned in Fig. 2

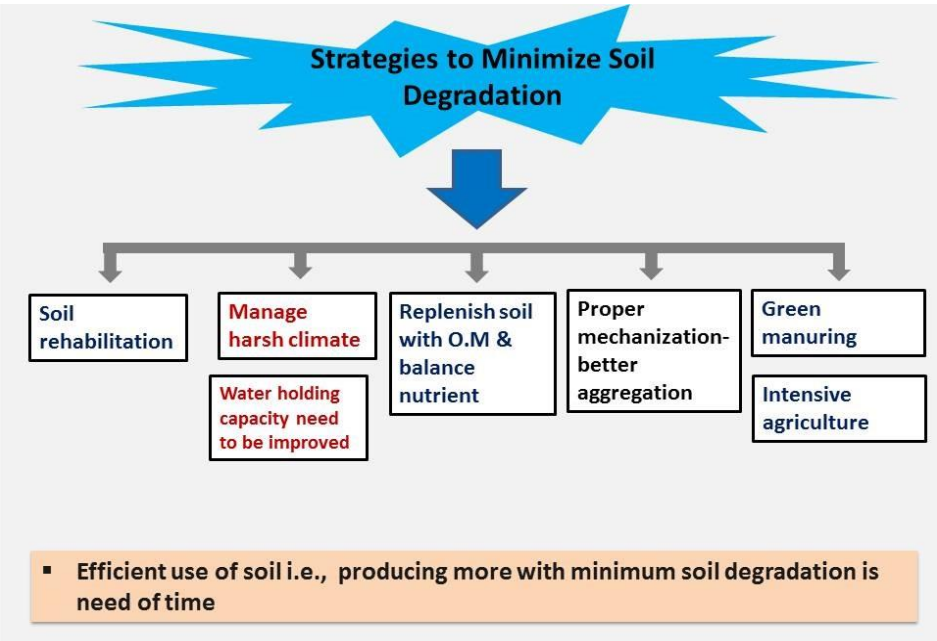


Figure 2. Strategies to minimize soil degradation

Role of seed and its variety in improving yield of crops

Keeping all other factors constant, seed rate determines the plant population in a field and thus is an important yield determining factor (Khan, 1994). Seed should be certified and seed rate should be used according to the recommendations otherwise yield will be affected. Good quality water and appropriate number of irrigations enhance yield of crops. Similarly, plant protection measures including weeding, hoeing and application of pesticide to control

pest and disease attack need to be adopted (Lipton, 2001). The occurrence of weeds, pests and disease on crops is increasing problem in all areas of Pakistan and adoption of chemical methods is progressively more popular.

A lot of lives depend upon the degree to which crop genetic improvement can keep pace with the growing global population, changing climate, and decreasing environmental resources. But genetically improved seed is only one part of the solution. Such seeds must be integrated into ecologically based farming systems and evaluated in light of their environmental, economic, and social impacts, in order for them to become a part of sustainable agricultural. However, there are some constrains related to the development of new variety, such as long time requirement, lack of funding for such long projects and lack of government policies (Lipton, 2001). On top of that variety approval system is very complicated. Increased production and food security may be achieved with the development of high yielding and input responsive crop varieties. There is a need to develop short duration verities for multiple cropping. Post-Green revolution expectation of yield improvement from the development and the release of newer higher yielding varieties have been overshadowed by problems resulting from increased cropping intensity, use of poor quality groundwater, low fertilizer efficiency, and increased weed and disease attack. Nonetheless development of new varieties is pre-requisite for enhancing agricultural growth & food security.

Conventional/non-conventional sources of fertilizers/growth promoters for enhancing fertilizers use efficiency

Balanced fertilizer application is a prerequisite for higher and sustainable yields. Farmers need be educated on the fact that all nutrients contribute equally. Introduction of slow release fertilizers, nanofertilizers and polymer coated fertilizers shows much promise for sustainable agriculture (Dorward, 1989). In addition, market availability of products in a form readily available to crops is yet another crucial factor that is seriously affecting farmers' ability to enhance productivity. Accordingly, there is a need to develop an effective fertilizer with the use of plant growth promoting bacteria to enhance bioavailability of immobile/less mobile macro- and micronutrients in order to reduce losses and improve agricultural productivity. These PGPB impregnated mineral fertilizers or PGPB inoculated organic fertilizers have multifacet edge over standard fertilizers. Additionally, the blended/ hybrid fertilizers release nutrients slowly resulting in minimum losses. Thus, FUE could be enhanced. Another positive aspect in the provision of multiple nutrients (macro + micro) which not only results in biofortification required in food security but also reduced the cost of inputs. Some possible ways to increase the fertilizers use efficiency are highlighted in Fig. 3

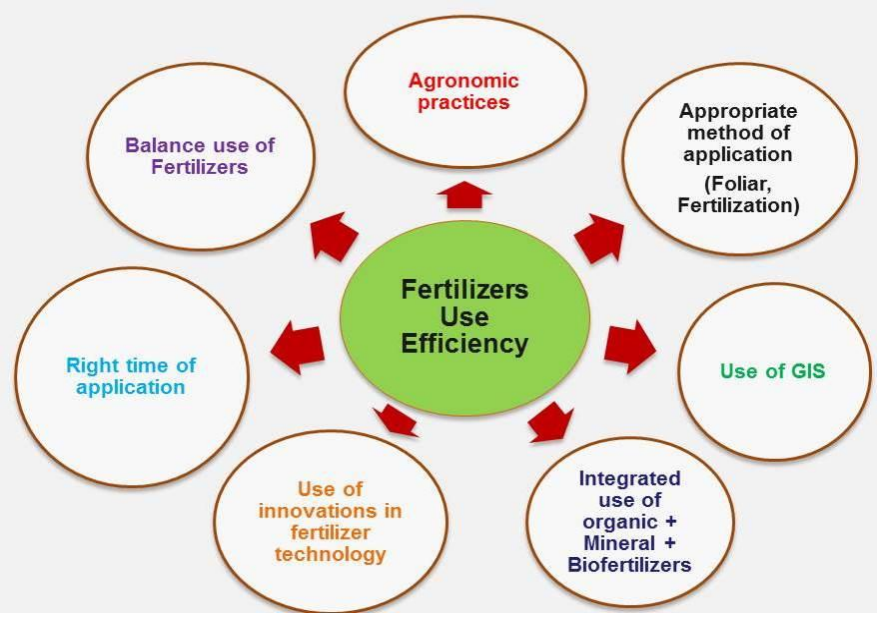


Figure 3. Possible means to enhance fertilizer use efficiency

Water use efficiency

Present and future scenario demands that that we should undertake all the measures for efficient use of water otherwise water availability are getting the most serious challenge to food security. Change in climate/environmental conditions posing serious question mark to the availability of water for all purposes including irrigation. Some possible ways to increase the water use efficiency are mentioned in Fig.4

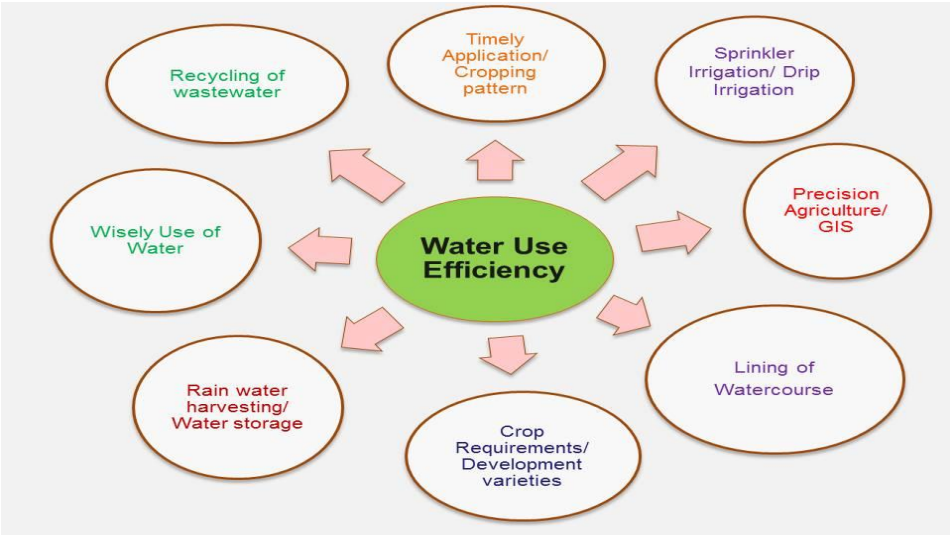


Figure 4. Possible means to enhanced water use efficiency

Effect of climate change on soil

The most recent report of the intergovernmental panel on climate change (IPCC) indicates that the average global temperature will probably rise between 1.1 and 6.4 ºC by 2090-2099, as compared to 1980-1999, with the most recent rise being between 1.8 and 4.0 ºC (IPCC, 2007a). Throughout history, temperature and precipitation have globally, regionally and locally changed. Therefore, even if we can't agree on why this climatic change is happening, it should be possible to agree that "it is happening" and with climate change there will be effects on environment, including the soil. Increased temperature, elevated CO_2 concentration near the soil surface and high precipitation rates lead to increased biomass. More crop residues and higher temperature also stimulate the activity of soil organism. Increased soil temperature also stimulates chemical weathering. On the hand, high rain fall as a result of global warming can wash out soluble nutrients at a higher rate from the soil surface resulting in soil erosion and nutrient loss. However the expected climate change and its effects on soils can vary to large extent. For example rising sea level will increase the flooding of coastal soils. Higher temperature in coastal soils may intensify the microbial formation of greenhouse gases. Permafrost soils may melt and their agriculture use may be partially possible. Secondly, changing climate will influence the carbon and nitrogen cycles, which will in tum affects, soil fertility (Hungate *et al*.,2003; Gorissen *et al*., 2004; Davidson and Janssens 2006; Wan *et al*., 2011) and will also affect soil moisture level (Chiew *et al*., 1995; Backlund *et al*., 2008; Kirkham, 2011).

Climate change is inevitable and ever-continued. No single approach will be effective, only multi-disciplinary integrated approach can work for the sustainable agriculture. The following integrated approaches are required to mitigate the climate change for sustainable agriculture.

Olive production in Pakistan

Olive trees require an arid climate to survive. They need a long, hot summer and a cool, not frigid, winter. A mature tree can survive temperatures down to 15 degrees F for a limited amount of time; sustained cold below 15 degrees can be fatal. Needs low water input but with high frequency. Required continuous but low amount of nutrients. When mineral fertilizer are applied to the olive crop in bulk amount, the vegetative growth of the olive tree will be more which result in less yield. In this regard slow release fertilizers are best suited to get maximum production of olive. So the use of integrated approach of biofertilizer /organic with mineral fertilizer will be the best approach to get maximum production of olive with minimum input.

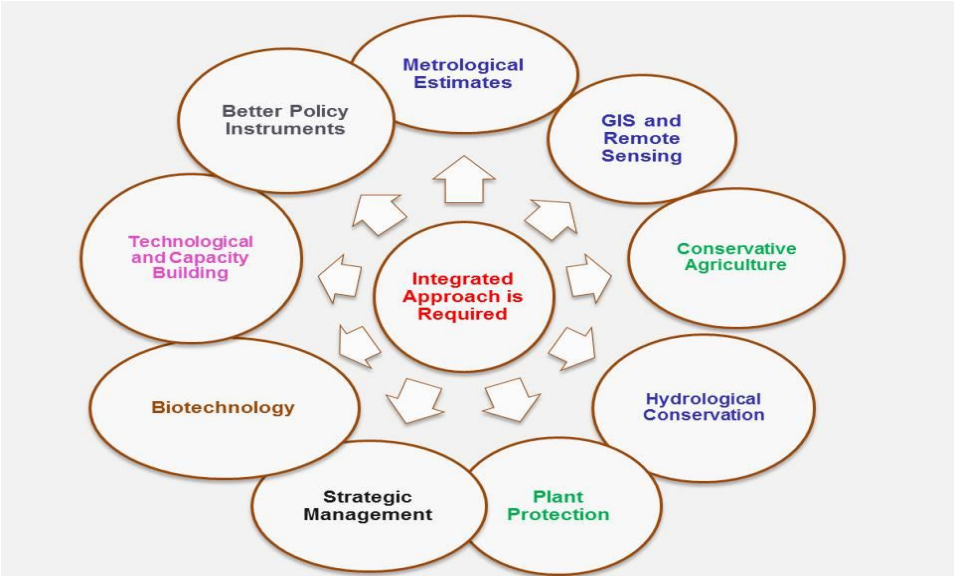


Figure 5. Mitigating Climate Change Effects

Yield gap between the science potential and the present level of productivity

The share of major crops in total value added in agriculture is 40.6 %. The four major crops namely wheat, rice, cotton, and sugarcane contributed 37 % to the overall agriculture income and around 9% of the GDP. Therefore, performance of these four crops has been crucial for agriculture production and overall performance of the economy. Fluctuation in yield performance of these major crops leads to unstable GDP growth rates. Share of minor crops in the Pakistan economy has been relatively small. The national average yields of various crops are far below their potential yields realized at the progressive farms and demonstrated at research stations. Moreover, research potential yields are lower than the potential demonstrated in many of the developed and developing countries. Evenson (2002) discusses four yield levels and three yield gaps associated with them (Fig 6).

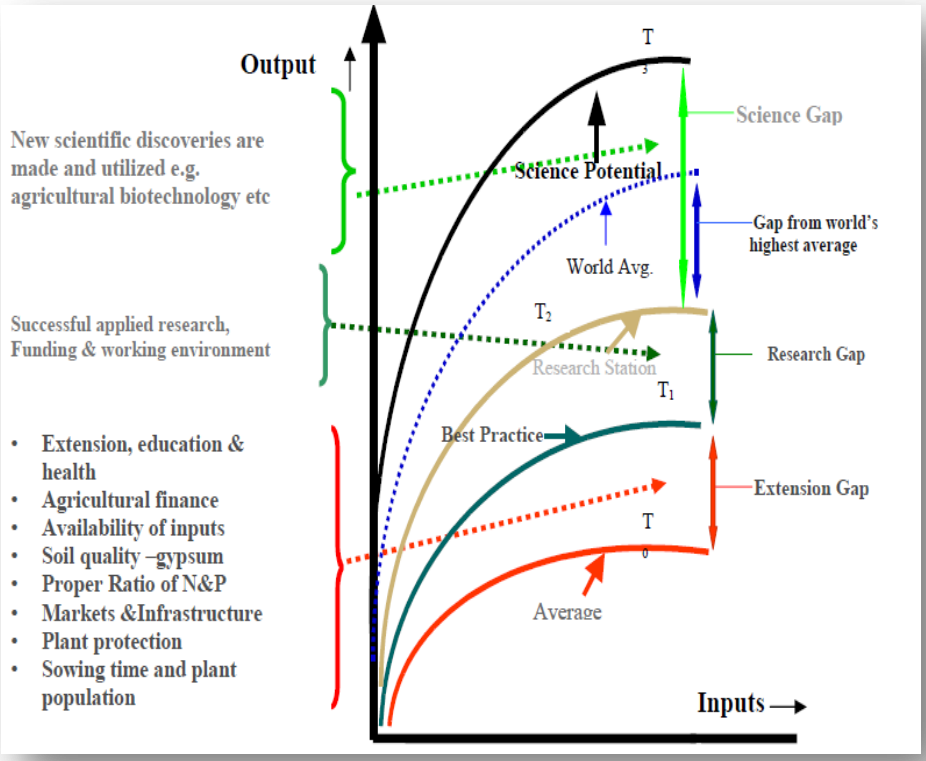


Figure 6. Productivity Gaps in Agriculture (Iqbal and Ahmad, 1999)

It is the research potential yield attained if new scientific discoveries are made possible using, modern research tools and biotechnological approaches are used in applied research programs. Associated with these four levels are three gaps. First, the extension gap is the difference between best practice and average yield. The extension programs are designed to shorten this gap. Second, the research gap is the difference between research potential yields and the best practice yield. Successful applied research programs will help to reduce this gap. Third, the science gap is the difference between science potential and research potential yields. Agriculture productivity growth would thus require frequently a shifting of T3 and T2 yields thus widening the research gaps and continually bridging this gap by enhancing the best practice yield (T1) through applied research. Science potential yield could be achieved with efficient use of resources. Thus in turn would expand the "extension gap" to be continuously bridged through effective extension services.

Conclusion

Efficient and wise use of soil, water and fertilizer (Integration of mineral/bio/organo fertilizer) could be the key for a success story for more yields of crops in Pakistan under changing environmental/climatic conditions with less input. Improving access to institutional credit and quality inputs markets, health facilities; resource conservation; and promoting the adaptation of tested technologies are the keys to a productive and sustainable agricultural system.

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Climate change and its impacts on water resources of Indus basin

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Abstract

The rivers of the Indus Basin have glaciated headwaters and snowfields that, along with monsoon runoff and groundwater aquifers, are the major sources of water for Pakistan. Currently, about 50–80 percent of the total average river flows in the Indus System are fed by snow and glacier melt in the Hindu-Kush, Karakoram (HKK) part of the Greater Himalayas, with the remainder coming from monsoon rain on the plains. Upper Indus Basin region is one of the most heavily glacierized areas in the world outside the polar regions. There is compelling evidence that the HKH cryosphere is being impacted on by climate change, including pronounced temperature rises in the region, particularly at higher altitudes. Climate change impacts can also be observed in the overall retreat of glaciers, an increased frequency and magnitude of extreme weather events, and a shift in the monsoon patterns, all of which will affect water availability and glacier related hazards. Variability in the distribution and timing of snowfall and changes in snow and ice melt may be amplified by climate change, which has implications for managing basin water resources. Pakistan‘s already hot climate and changing patterns of snowmelt and precipitation exacerbate existing social and economic pressures on natural and water resources, availability. Lack of environmental flows to the deltaic area is likely to expose around 2.26 million people to water scarcity and food insecurity. Pakistan‘s further depreciation from a water-stressed to a water-scarce nation, due to anthropogenic activity and a changing climate, influences the country‘s capacity for food and energy creation. The facts that the Government of Pakistan has made no action plan to tackle these crises, a low public awareness and limited technical abilities create a more difficult path towards alleviating the climate change crisis.

Key words: Climate change; water resources; snowfall variability; Indus basin

Introduction

The impacts of climate change in Pakistan include increased variability of monsoon, receding of Himalayan glacier’s likely impact on Indus River System flows which may hamper agricultural production, decreased capacity of water reservoirs and extreme events including floods and droughts, degradation of ecosystems, biodiversity loss and saline water intrusion in the aquifers. Climate change may induce severe water stress, and Pakistan will face food insecurity due to decreasing agricultural production. Rising global temperatures will lead to an intensification of the hydrological cycle, resulting in dryer dry and wetter rainy seasons, and subsequently heightened risks of more extreme and frequent floods and drought. Changing climate will also have significant impacts on the availability of water, as well as the quality and quantity of water that is available and accessible. Melting glaciers will increase flood risk during the rainy season, and strongly reduce dry-season water supplies to one-sixth of the World’s population.The fact is that global warming was unequivocal and there is no scope for scientific questioning. Pakistan is responsible for only a small fraction of global warming but is among the countries that will be hit hardest by the effects of climate change, Pakistan is witnessing severe pressures on its natural resources and environment. Climatic changes are likely to exacerbate this trend. Water supply, already a serious concern in many parts of the country, will decline dramatically, affecting food production. Export industries such as fisheries will also be affected, while coastal areas risk being inundated, flooding the homes of millions of people living in low-lying areas.
Although Pakistan produces minimal chlorofluorocarbons and emits little sulphur dioxide, thus making a negligible contribution to ozone depletion and acid rain, it will suffer disproportionately from climate change and other global environmental problems.

Linked to water is the food security of the country: around 90-95% of the freshwater resource is used by the agriculture sector, which contributes 22% to the GDP. Moreover, the sector employs 43% of the total labour force of Pakistan, with around 68% of livelihoods totally dependent on it. Analysing the situation for the Rabi crops, a study was conducted to assess the impact of climate change on the productivity of the wheat crop in four different agro-ecological zones, results showed that the length of the growing season for wheat will decrease with an increase in average temperature for all agro-ecological zones in Pakistan. Keeping the present water regime (irrigation and rain fed) and availability as per projections in perspective, with a temperature increase in the range of 1-5ºC, the wheat yield will drastically decrease in the sub-mountainous, arid and semiarid areas (GCISC,2009). It is to be noted that more than 90% of wheat is at present grown in arid and semi-arid areas; hence, any such increase in temperature can have a direct effect on the most important food items of Pakistan. For the time being, the total water situation during the Kharif period

(Summer Crop) is generally good allowing for the cultivation of cotton and rice in Punjab and Sindh. The monsoon further facilitates these crops. However both rice and cotton, despite being the prime export crops of Pakistan, are heavily taxing on water and this can have ramifications under Climate Change as rainfall might go through alterations as a result.

Most national and provincial development plans continue to focus on the role of infrastructure in addressing challenges of water and agriculture. However, recent documents highlight the increasing importance of improving irrigation efficiency and reducing fiscal shortfalls in the irrigation revenue system. Moreover, increasing yields is identified as a key area of needed improvement, particularly as it relates to adaptability to climate change (for example, accelerated crop breeding and adoption of genetically modified Bt cotton). Various forums and policy reports increasingly recognize the important role that water management plays in agricultural productivity; however, this relationship is not always comprehensively addressed in federal and provincial planning documents and budgets. This discrepancy underscores the need to address sector gaps and reduce uncertainties among the irrigation, agricultural, and climate change policies for Indus Basin management.

Water resources

A major part of the snow and ice mass of the Pakistan's Himalaya-Karakoram-Hindu Kush (HKH) is concentrated in the watershed of the Indus basin. Upper Indus Basin (UIB) watershed can be divided into distinct ten river sub-basins. A study was carried out in these ten sub-basins of HKH region of the country by Water Resources Research Institute of PARC. This study was based on Remote Sensing data of LANDSAT ETM+ of 2000-2001 period (Roohi, et.al., 2005). Glaciated area, no of glaciers and ice reserve of each sub-basin has been shown in Table 1.

Table 1: Summary of glacier inventory

S.No.	Sub-Basins	Basin Area (Km^2)	Glaciated area (Km^2)	No. of Glaciers	Ice Reserves (Km^3)
1	**Swat** (3)	14656	223.55	233	12.22
2	**Chitral** (3)	15322	1903.67	542	258.82
3	**Gilgit** (2)	14082	968.10	585	83.35
4	**Hunza** (2)	16389	4677.34	1050	808.79
5	**Shigar** (2)	7382	2240.08	194	581.27
6	**Shyok** (2)	10235	3547.84	372	891.80
7	**Indus** (1,2,3)	32571	688.00	1098	46.38
8	**Shingo** (1)	4680	36.91	172	1.01
9	**Astor** (1)	4214	607.03	588	47.93
10	**Jhelum** (1)	9198	148.18	384	6.94
	Total	**128730.8**	**15040.70**	**5218**	**2738.51**

1: Himalaya, 2: Karakoram, 3: Hindu kush, (Note: Parts of Indus sub-basin lies in all 3 ranges)

River flows

The major eastern tributaries are the Jhelum, Chenab, Ravi, Sutlej, and Beas rivers, while the major western tributaries are the Kabul and Kurram rivers. In addition, there are numerous small tributaries, such as the Soan and Haro rivers, and hill torrents, which drain either directly or indirectly into the Indus basin. The flows in all these rivers are quite variable in different cropping seasons and years. About 84% of flows occur in the Kharif (summer) crop season and only 16% occur in the Rabi (winter) season. The surface water resources in the country are constituted by precipitation in the catchment area or the area that drains into the river of the Indus river system, and of glacier melt in the upper basin.

Climate change impact on water resources

The effect of climate change on water resources is expected to be significant. An analysis of changes in the hydrological regime can provide a basis for estimating the impacts of climate change on water resources, and can be used as a tool to recommend changes in the water management regimes.

Climate Change Impacts On Himalaya Range Glaciated Resources

Glacial lakes were identified and their extent was estimated using remote sensing data for two periods 2001-02 and 2013. Area and number of lakes for these periods has been shown in Fig. 1. There were 2420 lakes in 2001-02 which were increased to 3044 in 2013 whereas lakes area increased to 134.8 sq. km in 2013 from 126.5 sq. km in 2001-02. The number and area of lakes is decreased in Swat and Chitral basins compared to all other basins where both number of lakes and corresponding area has increased.

Changes in glacier lakes during 2001-2013 period

Basin	2001		2013		Change	
	Number	Area (km^2)	Number	Area (km^2)	Number	Area (km^2)
Swat	255	15.9	214	12.5	-41	-3.4
Chitral	187	9.4	116	5.8	-71	-3.6
Gilgit	614	39.2	660	37.8	46	-1.4
Hunza	110	3.2	216	9.2	106	6
Shigar	54	1.1	110	2.3	56	1.2
Shyok	66	2.7	270	6	204	3.3
Indus	574	26.1	815	32.4	241	6.3
Shingo	238	11.6	247	11.8	9	0.2
Astore	126	5.5	196	5.8	70	0.3
	196	11.8	200	11.2	4	-0.6
Total	2420	126.5	3044	134.8	624	8.3

	Year 2001-02	Year 2013
Glacial Lakes...	2,420	3,044
Lakes area sq. km	126.5	134.8
Potential D. Lakes..	52	36

Figure 1. Comparison of glacial lakes for 2001-02 and 2013 in UIB

Remote sensing image data coupled with topographic maps were used to identify and delineate boundaries of glaciers and glacial lakes in the Astor Basin of Himalayan Range to evaluate the impact of climate change on glacial environment. Five glaciers and five associated glacial lakes (Fig. 2) were selected in Astore basin of northern Himalaya. It comprises glaciers and associated glacial lakes in series, with one glacial lake – *Folvi* identified as potentially dangerous of outburst flood (GLOF). Spatial data layers of glaciers and glacial lakes were developed through on-screen digitization in GIS and using different analytical techniques and logical operators, the physical characteristics of glaciers and glacial lakes like surface area, elevation, glacial thickness and volume were determined. Fig. 3 (a), (b), (c) and (d) shows the glacier and glacial areas delineated from toposheet (1964), Landsat TM (1993), Landsat ETM^+ (2001) and SPOT (2005) respectively. There is a rapid depletion of glaciers in the recent decades as compared to 1960s (Fig. 2). During 1964-2005, total glaciers cover shows a depleting trend at rates ranging between 1.3 and 10.6 ha/year (Table 2).

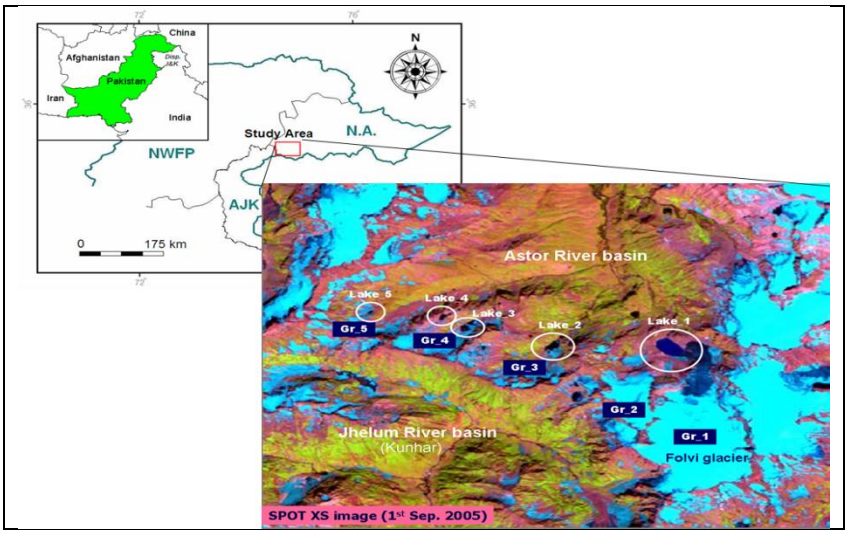
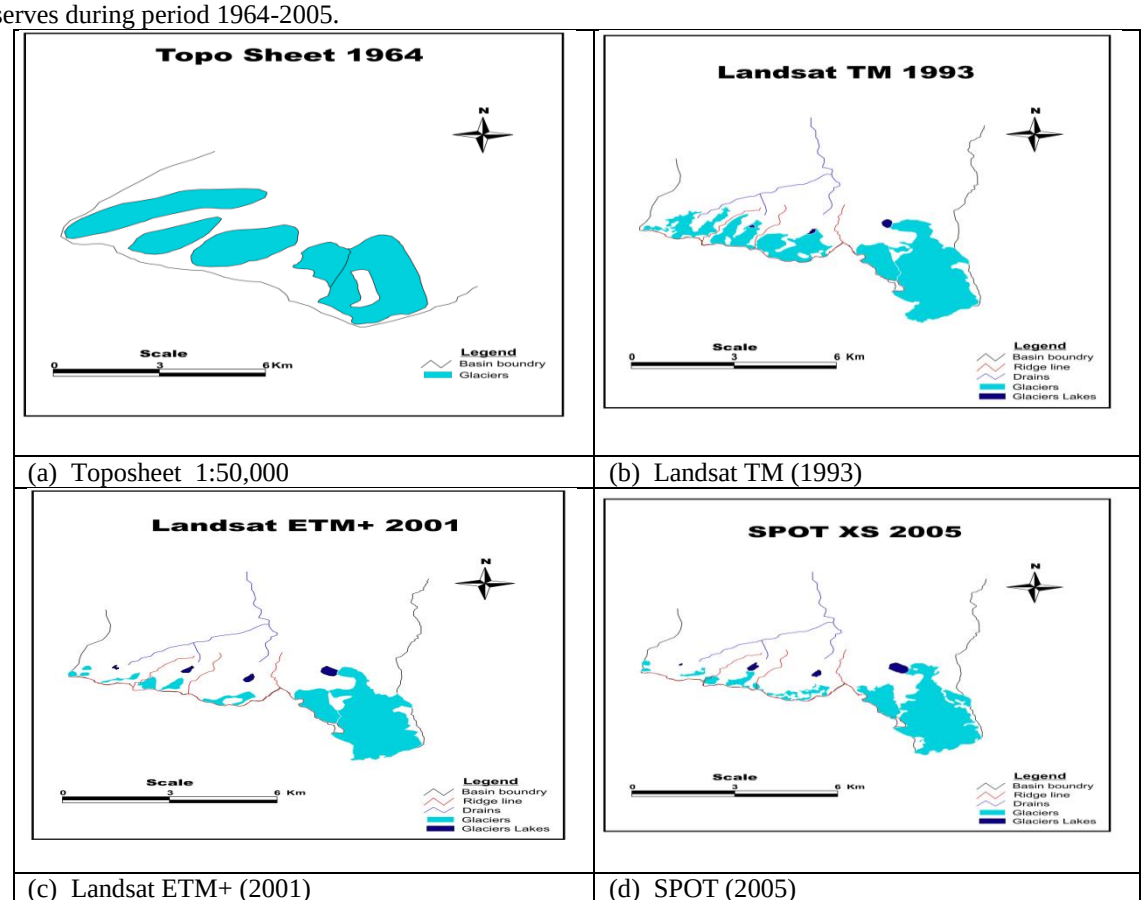


Figure 2. Location of Selected Glaciers and Lakes in Astore River Basin

The melting rates of small glaciers are higher than that of large glaciers. The melting rate of the largest glacier – *Folvi* (Gr 1) is about 1.3 ha/year which is minimum among other glaciers. There was a rising trend observed in Astor river flows during period 1974-2005. The situation may be attributed to the increase in contribution of snow and ice melts in the river flows. The increase in summer temperatures has affected the overall glacial coverage, thickness and ice reserves during period 1964-2005.



(a) Toposheet 1:50,000 | (b) Landsat TM (1993)

(c) Landsat ETM+ (2001) | (d) SPOT (2005)

Figure 3. Spatio-temporal analysis of glaciers and glacial lakes during last four decades

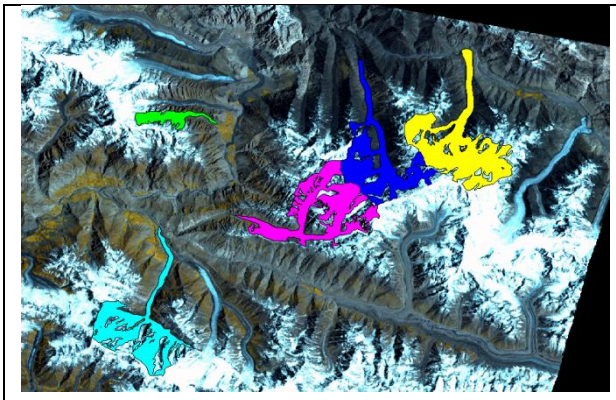
The melting of glaciers results not only in reduction of surface area and thickness of glaciers but also in expansion of the associated glacial lakes and creation of new one. The overall glacial lakes area shows an increasing trend during period 1993-2005.

Table 2: Temporal change in glaciers and glacial lakes areas

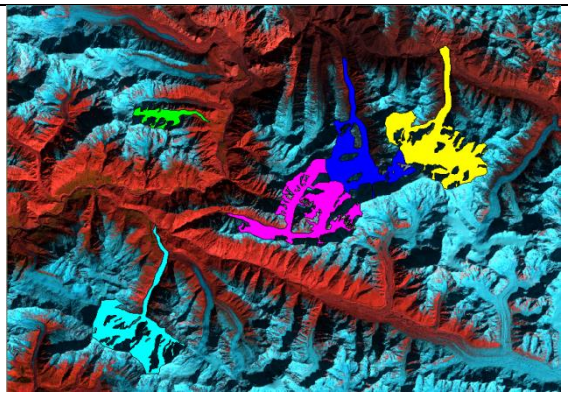
Gr/Lake No.	Glacier Area (1964-2005)				Lake Area (1993-2005)			
	1964	2005	Change (ha)	Rate (ha/yr)	1993	2005	Change (ha)	Rate (ha/yr)
1	717.1	661.8	55.3	1.3	13.0	21.9	-8.9	-0.7
2	218.8	123.8	95.0	2.3	3.3	7.3	-4.0	-0.3
3	393.0	56.9	336.1	8.0	4.0	8.1	-4.1	-0.3
4	214.9	48.7	166.2	4.0	2.4	2.8	-0.4	0.0
5	509.1	62.2	446.9	10.6	0.9	1.0	-0.1	0.0
Sum	2052.9	953.4	1099.5	26.2	23.6	41.1	-17.5	-1.3
Average	410.6	190.7	219.9	5.2	4.7	8.2	-3.5	-0.3

Climate change impacts on Karakoram range glaciated resources

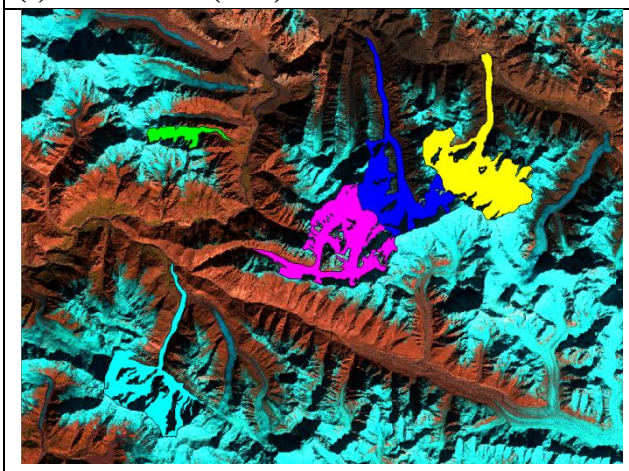
To study the climate change impact on glacier behaviour in Korakurm Range, five glaciers were selected in the Hunza River basin. The glacier boundaries were delineated using satellite remote sensing data of Landsat MSS (1979), Landsat TM (1993) and Landsat ETM+ (2003) as shown in Fig. 4a, 4b and 4c. Temporal variation in surface area of the glaciers had shown mix trend as given in Fig. 4d. Mulungutti glacier indicated a slight decrease in area while Momhil and Gharesa an increase in surface area.



(a) Landsat MSS (1979)



(b) Landsat TM (1992)



(c) Landsat ETM+ (2000)

Glacier	1979	1992	2000
Mulungutti	97.96	97.25	96.35
Momhil	73.48	75.59	75.04
Gharesa	70.23	81.77	83.05
Bualtar	63.69	63.63	63.46
Gulmit	14.21	14.05	14.07

(d)Trend of Selected Glaciers Area (km^2)

Figure 4. Spatio-temporal analysis of selected Karakoram glaciers

Climate change impacts on river flows

The annual variation in river flows was studied for Gilgit River at Gilgit, Swat River at Chakdara, Kunhar River at Naran and Gari Habibullah. Gilgit and Swat Rivers had indicated large annual discharge variations as shown in Fig. 5a. Kunhar River at Naran had shown relatively uniform annual flows. Gilgit River showed an increasing trend in flows. Mean maximum discharge of Gilgit River was found in July while minimum in the month of March Fig. 5b. Though Swat River had shown a similar pattern of flows as that of Gilgit River but the quantity was almost one third

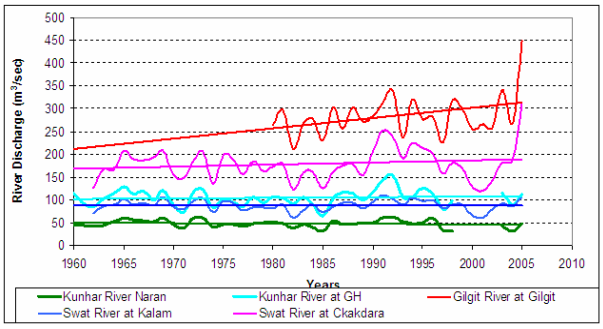
less in magnitude Fig. 5c. Climate change impact on river flows has been studied by WAPDA and its results have been shown in Fig. 5d. Climate change scenarios of -3 ^{o}C and reduction in glacier area of 50% have been adopted. Reduction of Annual River flows by 15% and inter-annual change in flow pattern have been resulted.

Conclusion

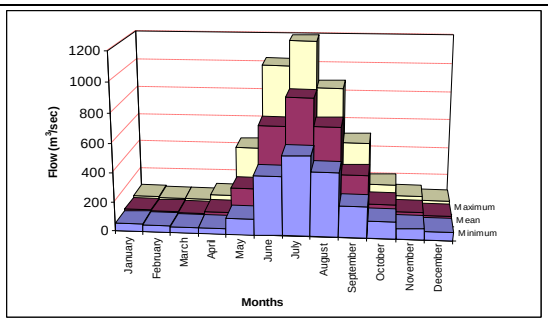
The situation about the impacts of climate change on Pakistan's water resources is complex and uncertain due to lack of extensive hydro-meteorological data available of Upper Indus Basin and limited studies executed on snow and glaciers resource of HKH ranges. The global warming has affected the overall snow-glacier environment of the Himalaya Range of Pakistan. The glaciers in Astore part of Himalaya were more or less in receding phase exhibiting variable rates of depletion. Some of the glaciers had shown higher depletion rates. The small glaciers are melting more rapidly than the large glaciers. The recession of glaciers has accelerated in the recent years. All these analysis are based on remote sensing based investigation without any in-situ field verification.

The climate change phenomena and its implications need to be studied more systematically in agriculture country like Pakistan in order to develop effective strategies for its risk mitigation and adaptation.

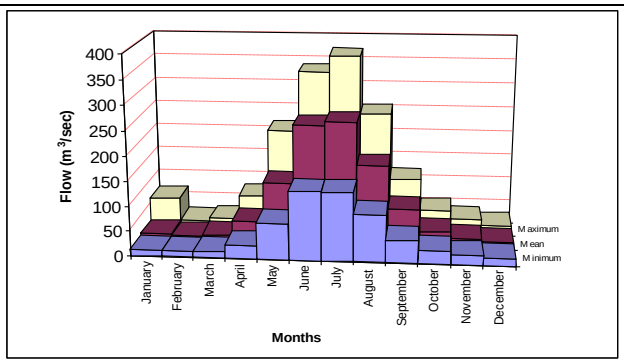
The impacts of global warming on glacier environment of Northern Pakistan need to be investigated in detail in order to cope up with the situations like of diminishing water resources and flood hazards in the downstream areas.



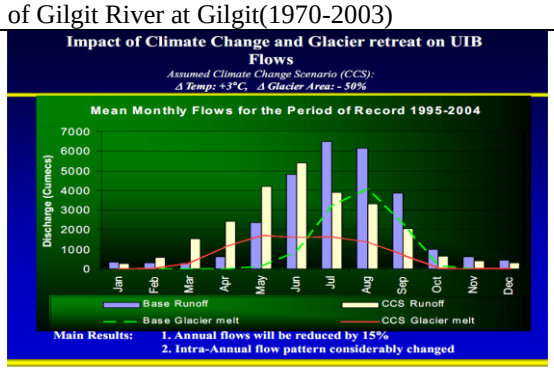
(a) Variability in annual flows of selected rivers



(b) Monthly mean, maximum & minimum flows of Gilgit River at Gilgit(1970-2003)



(c) Swat River at Kalam - monthly mean, maximum & minimum flows (1962-2003)



(d) Climate change impact on river flows by WAPDA

Figure 5. Situation of selected rivers flows of Indus River system

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Management of brackish water for irrigating sunflower (*Helianthus annuus* L.) through integrated use of potassium and farm yard manure

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Abstract

Use of brackish water for irrigating the agricultural lands is becoming a common and a wide spread practice throughout the world, particularly in arid and semiarid regions including Pakistan where freshwater resources are becoming scarcer. In Pakistan, about 70-75% of total water being pumped out is of brackish nature and injudicious use of this water is deteriorating the soil health and crop productivity. Brackish water can, however, be made productive through the addition of various chemical and organic amendments. In this experiment, brackish water (EC = 5.56 dS m^{-1}, SAR = 17.3 (mmol $L^{-1})^{1/2}$, RSC = 5.24 mmol L^{-1} was used to irrigate sunflower (*Helianthus annuus* L.) by supplying different levels of potassium (K) and farm yard manure (FYM) on non-saline, non-sodic clay loam soil. Ten treatments including T_1: fresh water (control); T_2: brackish water (BW); T_3: BW+K_1(100 mg K_2O kg^{-1} soil); T_4: BW+K_2 (200 mg K_2O kg^{-1} soil); T_5: BW+FYM_1 (5% FYM w/w); T_6: BW+FYM_2 (10% FYM w/w); T_7: BW+K_1+FYM_1; T_8: BW+K_1+FYM_2; T_9: BW+K_2+FYM_1; T_{10}: BW+K_2+FYM_2 were arranged in completely randomized design with five replications. Results revealed that plant growth and yield components including shoot dry weight plant height, head diameter, number of achene $head^{-1}$ and achene yield pot^{-1} were significantly ($P \leq 0.05$) decreased by brackish water irrigation without any amendment. However, when brackish water was used in combination with different amendments, plant growth and yield were markedly improved. All treatments were found to be highly effective to mitigate the adverse effects of brackish water but use of K_2+FYM_2 showed superiority over others in improving plant growth under brackish water irrigation. In conclusion, K and FYM mediated reduction in Na^+, Na^+: K^+ ratio, while increase in K^+ accumulation were the main factors contributing to improved adaptation of sunflower to brackish water irrigation.

Key words: Amendments; brackish water; FYM; potassium; soil health; sunflower

Introduction

Sunflower (*Helianthus annus* L.), an important oilseed crop, is sown on an area of 25 million ha all around the world (FAO, 2008). It is a major oil seed crop of Pakistan, cultivated on about 523 thousand acres with the production of 265 thousand tones. The sunflower seed is used not only for the industrial production of table oil or bio diesel, but also for the production of cold pressed table oil, husked seeds, roasted or fresh, that could be used whole or grounded in different foods. Its seed contains 35-55% oil contents. The average yield of sunflower in Pakistan is 1.3 tons ha^{-1} which is far below its yield potential. Among many factors, acute shortage of good quality irrigation water and the subsequent use of brackish water for irrigating crop is a menace responsible for dipping its average yield each year. In Pakistan, existing canal network could supply only one cusec water for 350 acres compared to 70 acres in USA (Ashraf *et al*., 2005). Furthermore, 70-75 of existing tube wells are pumping water of brackish nature (Latif and Beg, 2004). Hussain *et al*. (2008) reported that in Pakistan bout 67,842 million m^3 pumped water is brackish in nature due to high concentration of soluble salts and/or sodium ions (Na^+), above the permissible limits for irrigation. Injudicious use of these brackish waters results in the development of soil salinity/ sodicity on 3 x 10^6 ha in the country. Cucci and Lacolla (2013) reported that continuous use of brackish water without proper management may adversely affect the plant growth by influencing the uptake of plant essential nutrients, water relations, membrane stability index and plant metabolism.

Brackish water can, however, be effectively used for irrigation if proper management practices like addition of farm yard manure (FYM), green manure, poultry manure biofertilizers, inorganic nutrients and commercial acids, are followed (Ghafoor *et al*., 2001; Qadir *et al*., 2001). Hormick and Parr (1987) reported that addition of organic materials is of utmost importance in improving the plant growth and soil properties which are otherwise deteriorating when brackish water is being used. According to Murtaza *et al*. (2002) brackish water can be used safely for irrigation with proper management practices without considerable loss to soil health and crop productivity.

Potassium (K) is the third most important plant nutrient and is involved in numerous growth processes in sunflower such as photosynthesis, enzyme activation, stomatal activity, synthesis and transport of sugars, starch and protein, water and nutrient transport and eventually crop quality. Potassium appears to be readily displaced from membrane binding sites in plants by Na^+ under saline water irrigation and therefore, an alternative way to improve plant

salt tolerance is to increase the level of endogenous K by applying K salts (Akram *et al*. 2009). Cakmak (2005) reported that maintaining an adequate supply of K in saline soil solution could be an important factor for controlling the salt toxicity in crops irrigated with brackish water. Tabatabaei and Tabatabaei (2008) also reported that deleterious effects of salts could be alleviated by supplying K.

Keeping in view the possibility of utilizing brackish water for irrigating crops by adopting different management strategies like the use of organic manures, commercial acids, inorganic nutrients, biofertilizers etc., present study was planned with the following objectives;

- Evaluate the effect of saline-sodic water on growth and yield characteristics of sunflower.
- Evaluate the ameliorative role of K and FYM in improving plant growth and yield under saline-sodic water irrigation.

Materials and methods

A pot experiment was conducted to evaluate the ameliorative role of K and FYM in improving plant growth and yield of sunflower (*Helianthus annuus* L.) under saline-sodic water irrigation. Soil was collected from the top 20 cm depth of a cultivated field, air-dried, and passed through 2 mm sieve. Experimental soil was clay loam having pH 8.1, EC 2.5 dS m^{-1}, SAR 7.3 (m mol $L^{-1})^{1/2}$, organic matter 0.74%, N 22.6 mg kg^{-1}, P 3.5 mg kg^{-1} and K 127 mg kg^{-1} and $CaCO_3$ 7.1%. Earthen glazed pots having 28 cm diameter and 45 cm height were filled with 10 kg well prepared soil. Four healthy and uniform seeds of sunflower cultivar Hysun-33 were sown in each pot. Two seedlings in each pot were maintained after the germination. Plants were irrigated with brackish water having EC = 5.56 dS m^{-1}, SAR = 17.3 (mmol $L^{-1})^{1/2}$, RSC = 5.24 mmol L^{-1} by supplying different levels of K and FYM. Ten treatments including T_1: fresh water (control); T_2: brackish water (BW); T_3: BW+K_1(100 mg K_2O kg^{-1} soil); T_4: BW+K_2 (200 mg K_2O kg^{-1} soil); T_5: BW+FYM_1 (5% FYM w/w); T_6: BW+FYM_2 (10% FYM w/w); T_7: BW+K_1+FYM_1; T_8: BW+K_1+FYM_2; T_9: BW+K_2+FYM_1; T_{10}: BW+K_2+FYM_2 were arranged in completely randomized design with five replications. Recommended dose of nitrogen and phosphorus fertilizers (0.80 g N as urea, 0.50 g P_2O_5 as single super phosphate in each pot) and plant protection measures were applied to all treatments, uniformly.

Forty five days after treatment application, one plant from each pot was harvested and washed with distilled water. These plant samples were first air-dried and then oven dried at 70ºC for 48 h in an oven and weighed to get dry weight. Oven-dried plant samples were finely ground to 40 mesh. A 0.5 g portion of oven-dried samples of roots and shoots was digested in a mixture of concentrated nitric acid and perchloric acid (2:1,v/v) at 250°C. K^+ and Na^+ concentrations in root and shoot samples were estimated with a flame photometer (Yoshida *et al*., 1976). Second plant in each pot was allowed to grow up to maturity and used for yield determination. Data collected were subjected to analysis of variance (ANOVA) to compare the effects of treatments. The differences between the means were compared using the least significant difference test ($P \leq 0.05$) (Steel *et al*., 1997).

Results

Plant growth and yield characteristics in terms of plant height, biomass accumulation, head diameter, number of achene $head^{-1}$ and achene yield $plant^{-1}$ were significantly ($P \leq 0.05$) influenced when sunflower plants were irrigated with brackish water either alone or in combination with different levels of K and FYM. Fig. 1 indicated that maximum shoot dry weight was found in case of fresh water irrigation which was markedly reduced when plants were irrigated with brackish water without any amendment. However, when brackish water was used in combination with different levels of K and FYM, the shoot dry weight was significantly ($P \leq 0.05$) improved, with maximum improvement in case of higher K and FYM levels, compared to brackish water treatment without any amendment.

Plant height is an important morphological attribute which reflects the growth behavior of a crop. Besides genetic characteristics, soil nutrient status, seed vigor and environmental conditions also play vital role in determining the plant height. Plant height was significantly ($P \leq 0.05$) reduced when sunflower plants were irrigated with brackish water compared to fresh water (Fig. 2). Results revealed that plant height was markedly improved when brackish water was amended with both levels of K and FYM. However, ameliorative effect of K and FYM was more prominent when they used at higher levels and in combination compared to their lower levels and sole application.

Head diameter was significantly ($P \leq 0.05$) affected by brackish water irrigation used in combination with different levels of K and FYM. Maximum head diameter of 7.1 cm was found in case of fresh water irrigation which was reduced by 52% when sunflower plants were irrigated with brackish water without any amendment. Addition of K and FYM to brackish water treatments had great ameliorative effect and improved head diameter with maximum improvement of 79% and 73% in case of brackish water irrigation with co-application of K and FYM in lower and higher levels, respectively compared to brackish water irrigation without any amendment.

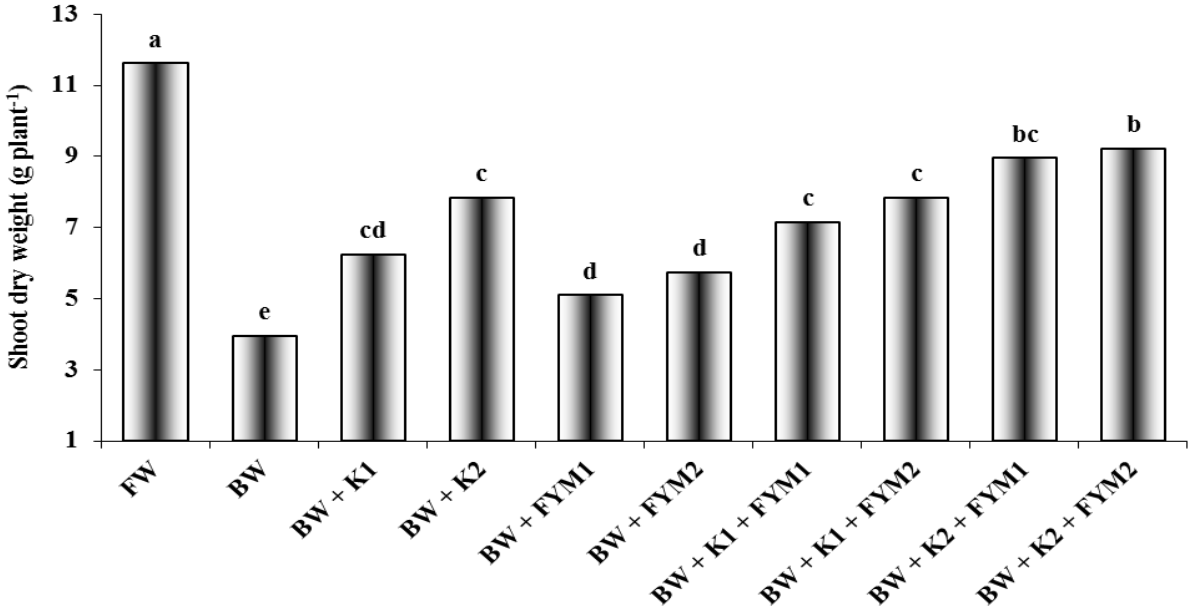

Figure 1. Shoot dry weight of sunflower plants grown with saline-sodic water using different levels of K and FYM (45 days old)

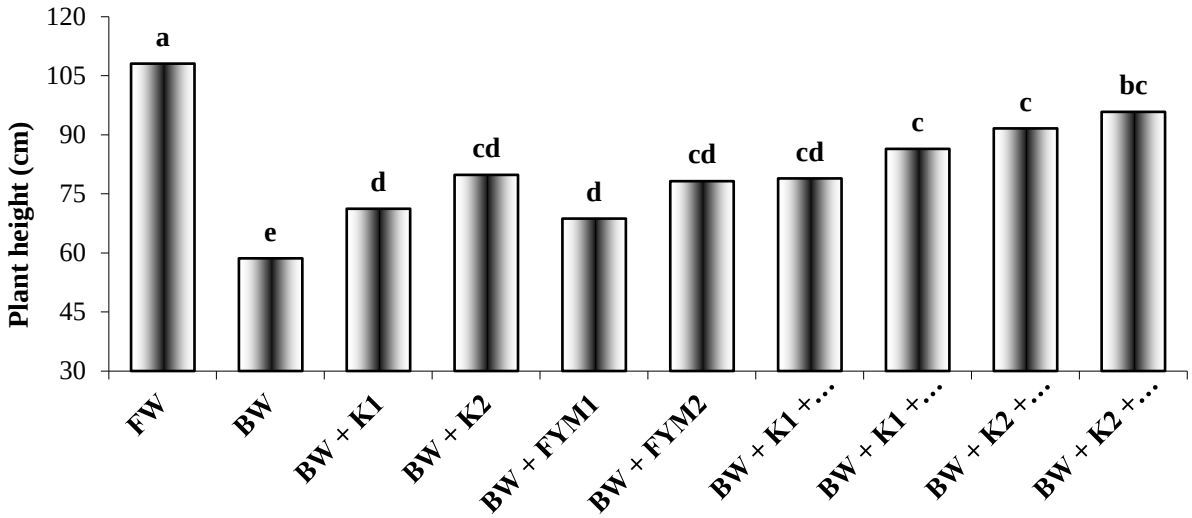

Figure 2. Plant height of sunflower plants grown with saline-sodic water using different levels of K and FYM (120 days old)

Data regarding the effect of brackish water, K and FYM on number of achene head^{-1} were presented in Fig. 4. Again, maximum number of achene head^{-1} of 256 was found in case of fresh water irrigation which was reduced by 52% by brackish water irrigation without any amendment. However, when brackish water was used with K and FYM, number of achene head^{-1} was significantly ($P \leq 0.05$) improved. Maximum improvement in number of achene head^{-1} was found when brackish water was used with combined application of K and FYM, particularly at higher levels of K and FYM.

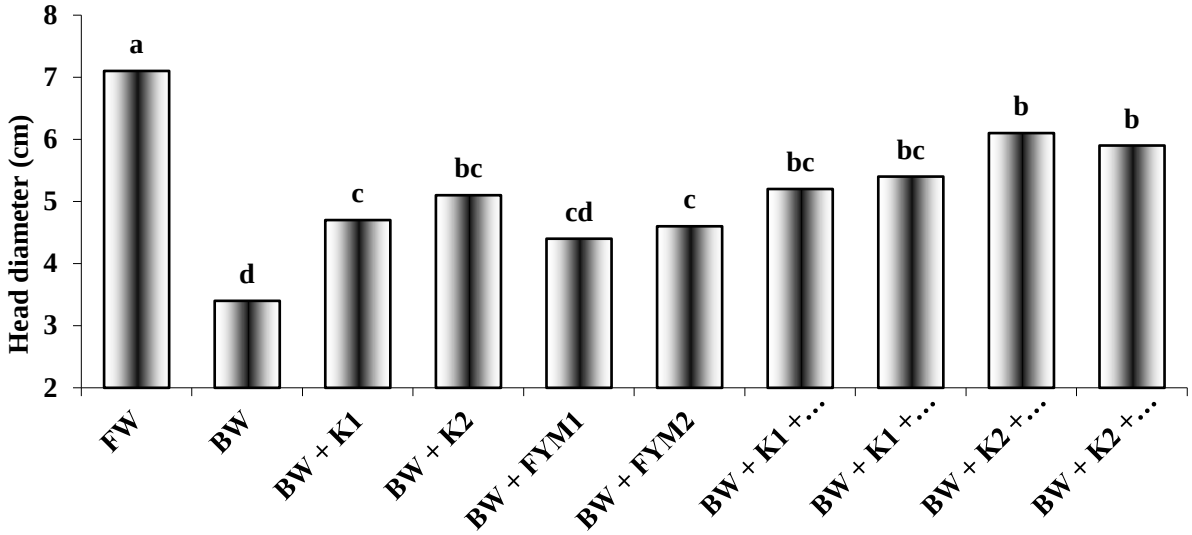

Figure 3. Head diameter of sunflower plants grown with saline-sodic water using different levels of K and FYM (120 days old)

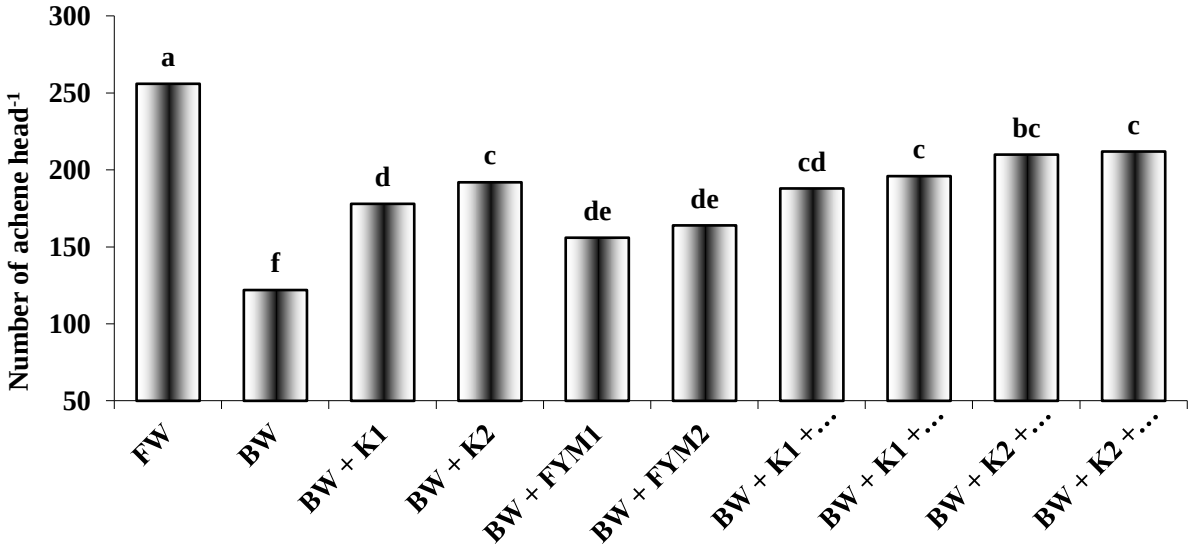

Figure 4. Number of achene head^{-1} of sunflower plants grown with saline-sodic water using different levels of K and FYM (120 days old)

Results regarding the effect of brackish water either alone or in combination with K or/ and FYM on achene yield of sunflower were presented in Fig. 5. Maximum achene yield plant^{-1} of 5.82 g was found in case of fresh water irrigation which was reduced significantly ($P \leq 0.05$) with the use of brackish water without any amendment. Potassium and FYM were proved very effective in alleviating the deleterious effects of brackish water and improved achene yield. Comparing the individual effects K and FYM, higher level of K and FYM were more effective to alleviate the ill effects of brackish water. Furthermore, combined effects of K and FYM in improving achene yield of sunflower under brackish water irrigation were more pronounced than their individual effects.

Fig. 6 indicated the effects of brackish water either alone or amended with different levels of K and FYM on Na^+: K^+ ratio in sunflower shoot. Maximum Na^+: K^+ ratio of 2.54 was found in case of brackish water treatment without any amendment. However, Na^+: K^+ ratio was significantly ($P \leq 0.05$) reduced when brackish water was amended with K and FYM. In brackish water treatments, minimum Na^+: K^+ ratio of 0.238 was found when brackish water was used for irrigating sunflower plants by amending with higher level of K+FYM. When comparing the individual effects of different levels K and FYM, higher levels of both K and FYM were more effective than lower levels in reducing shoot Na^+: K^+ ratio.

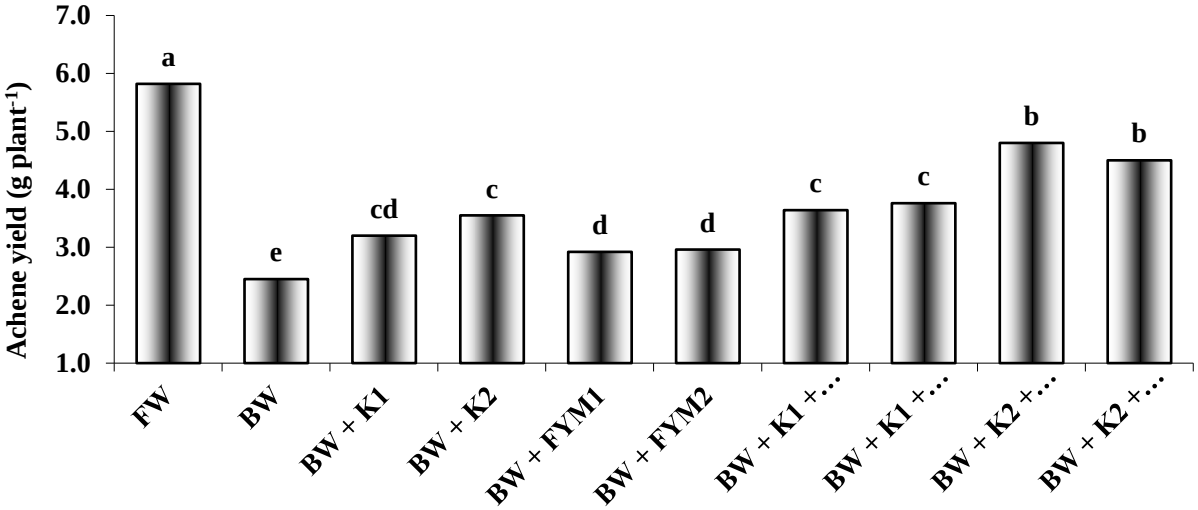

Figure 5. Achene yield of sunflower plants grown with saline-sodic water using different levels of K and FYM (120 days old)

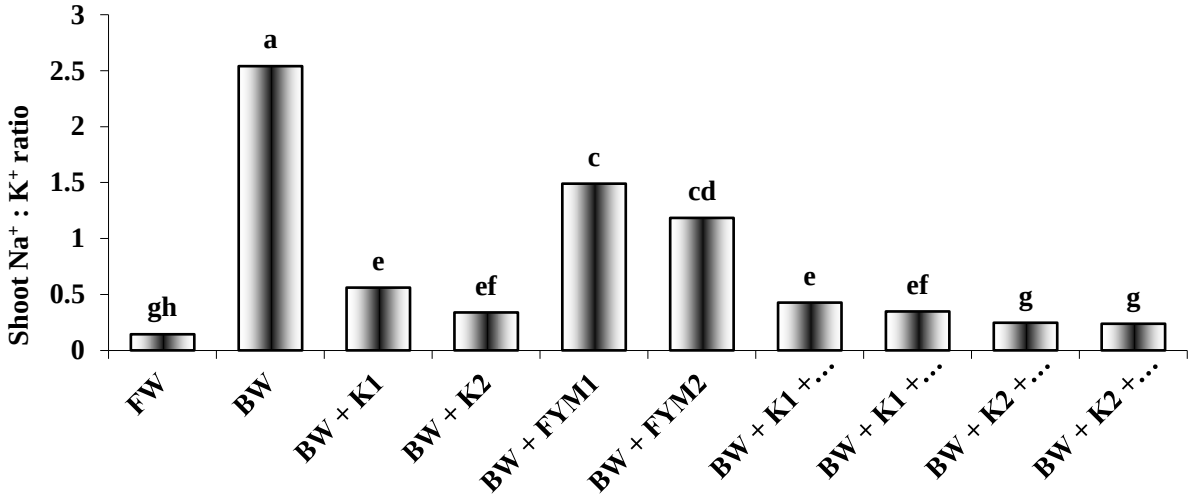

Figure 6. Shoot Na^+: K^+ ratio in sunflower plants grown with saline-sodic water using different levels of K and FYM (45 days old)

Discussion

Plant growth and development generally rely on four pillars, namely healthy soil, enough supply of good quality water, availability of high quality fertilizer and good quality seed. Water is vital for all biological system and living organisms, serves as transport medium, a solvent, a fuel for photosynthesis and many others. Water, particularly becomes a crucial resource in agriculture-based economies such as Pakistan, where almost 75% of total cropped area is under irrigation, which corresponds to 19.9 million ha. The shortage of water resources is getting more and more serious due to uneven distribution of rainfall and water resources in both time and space as well as due to rapid social and economic development that resulted in strong water competition among various sectors. It has been estimated that about 11 Mha of our land are lying as cultivable waste due to limited supply of good quality irrigation water and poor management practices (Federal Bureau of Statistics, 1987). Under these existing conditions, a supplemental source of water should be made to meet this deficit from underground water. Unfortunately the major portion of pumped ground water is unfit for irrigation and injudicious use of underground water for irrigation results in deterioration of soil physical and chemical properties (Ashraf *et al*., 2005). Brackish water can, however, be used successfully in agriculture by adopting soil, water and crop based technologies. In present study, saline-sodic water was used to irrigate sunflower using different levels of K and FYM. Brackish water irrigation caused a marked increase in shoot Na^+ while decrease in shoot K^+ with a resultant increase in shoot Na^+: K^+ ratio while decrease in plant growth and yield characteristics compared to fresh water irrigation. George *et al*. (2012) reported that high Na^+ built up in soil as the result of brackish water irrigation may disturb the uptake of water and mineral nutrients from the soil (Arzani, 2008) and produced

osmotic effect and nutrient imbalances with the subsequent reduction in plant growth and yield. Tahir *et al*. (2011) indicated that high Na^+ in root zone inhibited the uptake of K^+ resulting in increased Na^+: K^+ ratio and reduction in plant growth. Katerji *et al*. (2004) found that salt-induced imbalanced concentration of mineral nutrients in the root medium influenced the nutrient uptake from the soil and their subsequent utilization in the plant body. Application of K and/ or FYM has great ameliorative effect to alleviate the deleterious effects of brackish water and consequently improved plant growth and yield characteristics. Izhar-ul-Haq (2007) reported that application of different amendments like gypsum and FYM significantly effective to reduce the harmful effects of brackish water by lowering the EC, pH, and SAR of the experimental soil. Soil organic matter and K concentration in soil increased significantly while lime content decreased due to combined application of manure and gypsum. All these eventually resulted in improved plant growth and development. Among K and FYM, K was more effective to improve plant growth and yield under brackish water irrigation. While comparing the effect of both levels of K and FYM, higher level of K and FYM caused more improvement in plant growth compared to their lower level.

Furthermore, combined effect of K and FYM were more effective to alleviate the deleterious effects of brackish water than their sole application. Ashraf *et al*. (2005) conducted an experiment with brackish water using different organic amendments and reported that plant growth and yields of rice and wheat were significantly decreased with brackish water which was improved by the application of various organic amendments. All the three organic amendments i.e. pressmud, poultry manure and FYM were highly effective but poultry manure showed superiority over others in improving crop growth and yield under brackish irrigation water. Singh *et al*. (1992) also reported that application of different organic manures not only improved the plant growth and yields by reducing Na^+ concentration and improving mineral nutrient uptake, particularly of K^+ under brackish water-induced salt toxicity but also ameliorated the soil chemically as well as physically.

Conclusion

Sunflower showed marked reduction in plant growth and yield characteristics as well as K accumulation under saline-sodic water irrigation. Protection of metabolic processes and maintenance of high growth rate when saline-sodic water was supplemented with K and FYM frequently associated with restricted Na^+ uptake and accumulation, increase in K^+ concentration and decrease in Na^+ : K^+ ratio. Potassium and FYM-induced reduction in Na^+ uptake, Na^+: K^+ ratio while increase in K^+ accumulation, were the main protective mechanisms against saline-sodic water irrigation.

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Management and recycling of industrial wastewater for sustainable agriculture

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Abstract

Pakistan is one of the countries which are suffering from water scarcity problems. In Pakistan, the water availability has decreased from 1299 m³/capita in 1996-97 to 1100 m³/capita in 2006 and is further projected to be less than 700 m³/capita by 2025 which is very low as compared to the international standard of 1500 m³/capita. Due to this water scarcity, competition for good-quality water among different sectors is increasing and, hence, resulting into a decline in availability of water for agricultural irrigation. The most of the water taken away from agriculture is used for household, municipal and industrial activities which resultantly generate huge volumes of wastewater. According to an estimate, about 395×10^6 m^3/year wastewater is generated from the industry in Pakistan that is discharged into surface water bodies without any prior treatment. Despite that the industrial wastewater is loaded with a variety of pollutants/contaminants, it is being used to irrigate a range of crops in urban and periurban areas of several developing countries including Pakistan which are suffering from water scarcity. Moreover, with increasing water scarcity, these countries will have to increasingly rely on such non-conventional alternative water resources to narrow the gap between freshwater demand and supply for sustainable agriculture. However, the use of untreated or inadequately treated wastewaters for irrigation purposes in such developing countries is raising concerns not only about the environment but also the public health. Effective management and treatment of wastewater for its reuse in agriculture is well-established in developed countries but still limited in developing countries. Keeping in view the concerns arising from the use of wastewaters for agricultural purpose as well as the problem of water scarcity in developing countries, there is need to promote the management and recycling practices for the industrial wastewaters which might serve as an alternative water resource not only for providing greater certainty of water supply but also for offering a valuable nutrient source (as an equivalent to fertilizers). The present article presents an overview of the amount and nutrient composition of the wastewaters generated from different industries in Pakistan. Moreover, the biological treatment processes which might be helpful to exploit the industrial wastewaters for sustainable agricultural production by reducing their negative impacts on the environment and the public health have also been described in this article.

Wastewater generation from different industries in Pakistan

In Pakistan, various industries such as textile, petrochemicals, tannery, paper and pulp, food processing, refineries and sugar are working and generating a huge volume of wastewater. This water contains huge quantities of macronutrients and micronutrients. According to the report of Pakistan Water Sector Strategy PWSS (2002), total annual quantity of wastewater produced in Pakistan is 962,335 million gallons including 674,009 million gallons from municipal and 288,326 million gallons from industrial use. The industrial sub-sectors of paper and board, sugar, textile, cement, polyester yarn, and fertilizer produce more than 80% of the total industrial effluents (WB-CWRAS Paper 3, 2005). Murtaza and Zia (2012) reported the wastewater generation of 12 cities of Pakistan. Maximum wastewater was generated from Karachi followed by Lahore, Faisalabad, Gujranwala, Multan, Peshawar, Hyderabad, Rawalpindi, Sialkot and Sheikhupura.

Nutrient composition of industrial waste water

The wastewater generated by different industries (textile, tannery, ghee etc.) in Pakistan contains high quantity of different plant essential nutrients including nitrogen, phosphorus, sulfur, calcium etc (Table 1). For instance, Haydar and Bari (2011) analyzed the wastewater of Nishat Textile mill, Faisalabad for total nitrogen, phosphorus and sulfur. It was found that it contained 142.5, 32.5 and 0.7 mg L^{-1} sulfates, phosphates and total nitrogen, respectively. Similarly, atannery wastewater sample from East Pakistan Tannery, Sheikhupura had very high total Kjeldal nitrogen (236-358 mg L^{-1}) and sulfates (800-6480 mg L^{-1}). In effluent of Lyallpur Chemicals Ltd., which manufacture single super phopshate using rock phosphate and H_2S0_4 as raw materials, both P and K were found as 2.46 mg $L^{-1}$and 0.82 me L^{-1}, respectively. The wastewater of Pakistan Mhr Dying factor had 1.16 mg L^{-1}P and 1.28 me L^{-1}K (Ghafoor *et al*., 1994). Nosheen *et al*. (2000) collected fifteen samples from different textile mills of Faisalabad and analyzed for sulphate

content. The concentration range of sulphate ion in textile effluents was 200– 950. Hanif *et al*. (2008) compared the wastewater of dying and finishing unit, and it was observed that finishing unit had more nitrate, nitrites and sulfate content. In addition to major nutrients, these effluents also contain micronutrients such as Zn, Ni, Co, Cu etc required by plants in lesser amounts.

Table 1: Nutrient content of wastewater of different industries in Pakistan

Industry Type	Nutrient composition (mg/L)		Reference
	Nutrient type	Concentration (mg/L)	
Nishat Textile Mill, Faisalabad	Phosphates Sulfates Total Kjeldhal nitrogen	0.7 142.6 32.5	Haydar and Bari, 2011
Shahdara Drain, Lahore	Calcium Magnesium Sulfates	71 49 272	Hamid *et al*., 2013
East Pakistan Tannery, 27 Km Lahore-Sheikhupura Road	Total Kjeldhal nitrogen: Sulfates:	236-358 800-6480	Haydar *et al*., 2007
Hattar Industrial Estate Haripur (Ghee mil)	Potassium	6	Hussain *et al*., 2014
Lyallpur Chemicals Ltd.	Phosphorus Potassium (me/L) Sulfate (mmol/L)	2.49 0.82 8.90	Ghafoor *et al*., 1994
Pakistan Mhr Dying Factory	Phosphorus Potassium (me/L) Sulfate (mmol/L)	1.16 1.28 12.97	
Dying, bleaching and printing industry of Faisalabad	Sulfates	200-950	
Textile unit (Dying)	Nitrate Nitrite Sulfates	1.09 10.23 834	Hanif *et al*., 2008
Textile unit (finishing)	Nitrate Nitrite Sulfates	3.56 14.26 943	
Hyatabad Industrial estate, Peshawar	Sulfates Nitrates Phosphates	79-481 0.75-11.60 3.40-15.40	Bangash *et al*., 2006
Rehri Greek Area, Karachi	Phosphates	0.42-78.92	Khan *et al*., 2009
Sindh Industrial Trading Estate	Potassium Sulfates Nitrates Calcium Magnesium	3.85-29.7 122-1817 0.06-12.1 17.6-379.5 22-364.1	Rahman and Hashmi, 2014
Textile industry, Karachi	Sulfate Phosphates	8.82-18.38 1.1-2.59	Imtiazuddin *et al*., 2014

Effect of treated industrial wastewater on germination and growth of various crops

As a result of a rapid increase in global population, the gap between the supply and demand for clean water is widening and is becoming one of the major threats for human existence. This situation becomes even more complex due to high level use of water for different industrial processes resulting into release of huge amount of wastewaters loaded with diverse type of organic and inorganic contaminants. Despite that wastewaters are source of pollution, they also contain a considerable amount of different nutrient elements (As already described above) that can be applied for productive uses for use in agriculture, aquaculture, and other activities. Hence there is an increasing trend to devise the strategies for treating and using the wastewaters for agricultural irrigation and other purposes including recharge of

groundwater, landscaping, construction, dust control, industry, wildlife habitat improvement and aquaculture. However, here we will focus the studies related to the treatment of wastewaters for application in agricultural production. During the recent years, a number of researchers have conducted the studies on treatment of different types of wastewaters for their subsequent application in agricultural production either through increase in germination or through improvement in plant growth and yield (Parshetti *et al*., 2006; Saratale *et al*., 2009; Parshetti *et al*., 2011; Khalid *et al*., 2013; Najme *et al*., 2015). For example, Saratale *et al*. (2009) indicated that bioremediation of Navy blue HER dye based synthetic wastewater by *Trichosporon beigelii* NCIM-3326 resulted into a significant increase in the germination of *Phaseolus mungo* and *Sorghum vulgare* as compared to untreated synthetic wastewater. Similar types of findings have also been reported by Parshetti *et al*. (2006) while studying the biodegradation of Malachite Green by *Kocuria rosea* MTCC 1532 and by Parshetti *et al*. (2011) while studying the biodegradation of Crystal violet by *Agrobacterium radiobacter* MTCC 8161. Khalid *et al*. (2013) studied the possibility of agricultural application of synthetic textile wastewater treated through bacteria in a sequencing batch bioreactor. In this study, the treated and un-treated synthetic wastewaters were used to study their impacts on seed germination index, root length, shoot length and biomass production of pea and wheat. The results indicated that treated synthetic wastewater resulted into a significant increase in seed germination index, root length, shoot length and biomass production of both pea and wheat as compared to the un-treated wastewater. Most recently, Najme *et al*. (2015) conducted a study to evaluate the germination of *Vigna radiata* seeds in the presence of a reactive yallow-2 (1000 ppm) based synthetic wastewater and the products of reactive yellow-2 decolorization by *Serratia* sp. RN34. It was observed that *Vigna radiata* seeds showed only 41.7 % (± 7.60) germination when irrigated with reactive yellow-2 dye. However, the germination rate (86.7 ± 7.60 %) of the *Vigna radiata* seeds irrigated with the decolorized products of reactive yellow-2 was found to be statistically at par with germination rate (95.0 ± 5.00) of the *Vigna radiata* seeds treated with distilled water. The plumule length was significantly lower (4.7 ± 0.68 cm) in the treatments receiving reactive yellow-2 dye as compared to the treatments receiving distilled water (11.1 ± 0.69 cm). However, the plumule length was found to be significantly improved (9.8 ± 0.57 cm) when the seeds were irrigated with the decolorized products of reactive yellow-2. The similar type of response was observed in case of radical. The maximum and significantly higher radical length (7.1 ± 0.39 cm) was observed when the seeds were treated with distilled water. However, the radical length was significantly higher for the seeds irrigated with decolorized products of reactive yellow-2 (5.66 ± 0.37 cm) as compared to that of irrigated with reactive yellow-2 azo dye (1.67 ± 0.28 cm).

Based on the finding presented in this article, it might be concluded that wastewater treatment for subsequent application in different useful purposes including agricultural irrigation might serve as an effective strategy for recycling and reuse of the industrially contaminated effluents. However, before the practical application of such treated wastewaters, there is need to compare the composition of the wastewaters before and after the treatment to avoid any possible negative impacts of the treated wastewaters.

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Sustainable flood water management using geo-informatics approach: a review

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Abstract

Floods are most vulnerable ground hazard. The important parameter for estimating flood impacts are flood monitoring, mapping and inundation Present review paper has been highlighted that GIS and Remote Sensing are very effective and quick techniques for identification of flood prone area, monitoring, overview and assessment of flood impacts. Through these modern technologies detailed and timely analysis can be carried out. Different mentioned researches have been carried out on locating, identification of affected areas by flood as well as impact on different land cover features like crops. Moreover estimation of damages can also be calculated to get the total economic loss caused by flooding.

Key words: Land Use Planning; Mapping; Assessment; Policy Making

Introduction

Floods are most vulnerable ground hazard. Now days GeographicInformation System (GIS) and Remote Sensing (RS) is playing significant role in water resource management, hydrological modeling and assessing flood and its related damages (Werner, 2001; Dewan *et al*., 2007). For managers, land use planning, decision and policy makers RS is the most applied method for measuring, estimation and mapping of flood prone area and its impact (Hoque *et al*., 2011). In third world countries application of remote sensing is vital for observing geological changes like flooding, because it find difficult for governmental department and agencies to update their information database regularly by using earth observation techniques due to lack of financial aid and time associated with traditional methods (Dong *et al*., 1997). However further improvement in these facilities are continually carrying out for evaluation and assessment of hazards (Carrara and Guzzetti 1993).

Fate of floods in sub continent

Asian monsoon is act as trigger for flooding in Pakistan, India and Bangladesh as more and more rainfall occurring (Matsumoto 1997; Hofer and Messerli 2006). The important parameter for estimating flood impacts are flood monitoring, mapping and inundation. For these many methods have been developed to estimate and mapping extent of inundation (Imhoff *et al*., 1986, 1987; Ali *et al*. 1989; Rasid and Pramanik 1990, 1993; Chowdhury, 1996; Matsumoto *et al*. 1996; Matsumoto 1997; Smith 1997; Oberstadler *et al*. 1997; Otsubo *et al*. 2000; Rahman *et al*., 2005; Wilson and Rashid 2005; Dewan *et al*.2006; Hofer and Messerli 2006; Sakamoto *et al*. 2007).

In Pakistan rainfall occur during monsoon and western disturbances atmospheric circulation. Monsoon rainfall started from month of July and end up in month of September. During this shortest duration of monsoon season average 50cm monsoon is received in Pakistan as whole (Khandekar, 1996). But pre and post monsoon caused by climatic changes (ENSO) cause the sever impact on country population and economy. Different areas in Pakistan has been affected by flooding during monsoon season (July-September) since year of 1928. Years of Devastating flood effects have been experienced are 1928, 1929, 1955, 1973, 1976, 1980, 1988, 1992 and 2010 (Solheim *et al*., 2001; Kussul *et al*., 2008). In 2010, Pakistan flooding and their widespread impacts got high attention in scientific community and media.

Bangladesh is one of the most flood prone country in the world (Islam *et al*., 2014). In Bangladesh, floods are regular facing hazard in its capital Dhaka during monsoon season. Historical evidence have shown that disastrous floods have hit the Dhaka in past years especially flood of year 1998 (Faisal *et al*., 1999; Jahan, 2000; Dewan *et al*., 2004).
In India flood hazard must occurring more than once in five years due to monsoon season starting in June. Sometime flooding also hit those areas which were not considered earlier for flood or marked as non-flood prone areas (Gangwar, 2013).

Applications of remote sensing and gis in flood management

There are number of Remote sensing integrated GIS application regarding flood hazard management. Like this integrated technique can be used to measure crop damages, depth of Floodwater Depth, assessment of flood prone areas and land use planning necessary tool for disaster management. Presently remote sensing and GIS based monitoring activities for flood has been established all over the world (Joy and Lu, 2004; Karen *et al*., 2009).

Crop damages by flood

GIS/RS integrated technique is widely used for estimating damages to crops caused by flood. Objective of remote sensing regarding crop damage estimation is to generate spatial data layer having damage probability classes based on flood prone area, height and duration of flood, crop type and total covered area along phase of crop life phase. Then probability classes translate to actual crop damage classes based on field collected data. For this MODIS satellite images are easily available and used for crop damages in flood affected area.

Flood depth estimation

Though it is not easy to obtain information about depth of flood but in 2000 two researchers Islam *et al*. (200) suggested valid technique to obtain depth information from multi-temporal SAR images. Later on one research in 2007 by Ashraf *et al*. conducted for Bangladesh by using same methodology in order to get depth information of flood. Researchers used satellite imageries and Digital Elevation Model (DEM). From DEM, land map consist of four classes of height were generate to estimate depth. Supervised classification was applied to classify image in to four classes of flood height i.e. shallow, medium, deep, and no flooding (Ashraf *et al*., 2007).

Assessment of flood prone areas

Satellite remote sensing (SRS) is now widely using for hazard assessment. Though application of SRS has marked great potential for hazard assessment but the facing challenge is the lack of worldwide accepted methods for generating maps of hazard prone areas (McKean *et al*. 1991; Rhoads 1986). Besides there are many developed methods which have been used in developed countries but these methods are not accessible to developing nation particularly Pakistan and Bangladesh due to restriction on digital data sources. Like flood mapping based on DEM may not be possible until the high resolution digital elevation data is not available. For this problem one paper highlight to use ERDAS IMAGINE software to construct model in model marker utility in developing countries to evaluate and assess flood area (Ashraf *et al*., 2007).

Land use planning for disaster management

Land use planning is very useful tool for the disaster management. Remote sensing technique is widely using in developing map for hazard prone areas that can be used for decision making for development or for land use planning. Through this potential risk and damages caused by flood can be reduced. Different researches have highlighted the flood management plan through remote sensing and modeling in sub-continent, like in Dhaka (Hossain, 1998; Dewan *et al*., 2004; Dewan *et al*., 2005; Ashraf *et al*., 2007); in Pakistan (Shan *et al*., 2010; Hussain *et al*., 2011; Haq *et al*., 2012; Uddin *et al*., 2013); and in India (Thakur *et al*., 2012; Gangwar, 2013; Kundu *et al*., 2015).
Presently extracted information from GIS and RS integrated with other datasets (Pradhan *et al*., 2009) use for flood disaster monitoring and assessment of its impact (Pradhan and Shafie, 2009).

Conclusion

Present review paper has been highlighted that GIS and Remote Sensing are very effective and quick techniques for identification of flood prone area, monitoring, overview and assessment of flood impacts. Through these modern technologies detailed and timely analysis can be carried out. Different mentioned researches have been carried out on locating, identification of affected areas by flood as well as impact on different land cover features like crops. Moreover estimation of damages can also be calculated to get the total economic loss caused by flooding.

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Olive cultivation experiences in Abbottabad

Col. (Rtd.) Khalid Mahmood
Coordinator Corps of Volunteers

Geographical location of Abbottabad and climatic conditions here make it a suitable place for olive cultivation. Existence of hundreds and thousands of wild olive trees is further indication that this land provides favorable environment for olive growth. Lime stone slopes with frequent rainfall are also present in the area which is ideal ground for olive trees. Grafting wild olives with grafts from quality mother olive trees can convert the former into high quality olive bearing trees. A 6 years old tree grown in a house in Abbotabad bears 15 kg fruit annually.

Corps of Volunteers, an organization whose members are retired govt servants, private entrepreneurs and prospective olive farmers, has taken upon itself to promote the growth of olive in Abbottabad and beyond on self help basis. As a first step an awareness campaign was kicked off in 2011. Teams from Corps of Volunteers visited the villages and towns of district Abbottabad to educate the public in general and prospective farmers in particular on the benefits of olive cultivation. A very encouraging response was obtained. On 23 Dec 2011, with the cooperation of SMEDA and EDO agriculture and livestock- Abbottabad, a seminar on olive cultivation in Abbottabad was organized. Farmers from across the district participated in the seminar with lots of enthusiasm and fully made up their minds to embark upon growing of olive on whatever land they could afford besides getting their wild olive trees grafted with quality olive. The awareness campaign continued in the form of meetings, workshops and visits around. On 26 Feb 2012 a training session of one day was organized in a local olive orchard in Abbottabad where 37 farmers were trained in grafting techniques. This was followed by providing grafts to the interested farmers. An effort was made to encourage local army establishments to grow olive in their areas. Few hundred certified quality olive plants procured from various sources were distributed among the farmers on no profit.

A 50 x 17 feet nursery for olive cultivation has been established in Abbottabad on a land donated for the purpose by a gentleman. Olive saplings from Italy have been distributed by PARC to some of our members in 2014. Process of growing of olive in Abbottabad has been set in motion. Farmers' demand for grafts and saplings is on increase with every coming day. Demand of few is met by us through various sources. Others are guided directly to the source.

The Institute *Alcide De Gasperi* Institute for European Studies

Antonio Sabbatella
Alcide De Gasperi Institute for European Studies, Rome, Italy

The institute was established in 1953, thanks to the statesman Alcide De Gasperi, one of the founding fathers of Europe - along with Robert Schuman, Jean Monnet, Konrad Adenauer and Paul-Henri Spaak - and a key figure of Italy's post-World War II reconstruction. It is a highly specialized research and teaching centre in the field of European studies, operating at the postgraduate levels. It follows the latest educational innovations in teaching and carries out constant research activities aimed at developing the most relevant European issues.

In 1956 the institute was designated as a 'Moral Entity' (an institute of public interest) and is recognized as a centre for higher education by the Italian Ministry of Education. During its sixty-two years of uninterrupted activities in the field of research and training, the "Alcide De Gasperi" Institute has become a landmark in the field of European disciplines. But, the institute has always been appreciated not only for academic work, but also for its training in technical practice via courses supported by distinguished teachers.

Since its foundation, the Institute has always built connections with other international institutions and has developed working relationships with public and private universities in teaching and research, not only in Western Europe but also in Central and Eastern Europe, the former Soviet Union and North Africa. The teaching staff is composed of academics, experts, lawyers, judges, diplomats, politicians, EU officials, and this is another way of encouraging cross-sectorial and multi-disciplinary studies, not only within the academic world but also incorporating lessons from those working in EU institutions.

The Institute follows relevant innovations in teaching, and the subject matter of the studies include the main historical, legal, economic and security aspects of European integration as implemented within the EU as well as an overall survey of major pan-European and transatlantic institutions; the single market, the economic and monetary union and common policies, and the external relations of the EU.The institute unlike what might seem, promotes not only studies on legal issues, but also on socio-economic topics, agricultural matters, social and political cooperation and European and international integration.

The main areas of interest have been progressively developed during the fifty years of activity in the expanding sector of external relations of the European Union and, more recently, in the development and implementation of common foreign policy, especially with regard to the safety and cooperation for development.

The involvement with the project SAWaM-Pak

The water scarcity is an increasingly serious and concrete problem, as we know the project SAWAM Pak, has set as its aim to increase the productivity and efficiency of water use in agriculture and mitigate the impacts of increased drought.Our experts, with the aid of AGRFOR (Agronomists and Forest without borders) have developed a high experience in agricultural cooperation and in the fight against desertification in several African countries through the application of innovative techniques for soil remediation collecting storm water and agricultural production in countries with high aridity.

Moreover, our experts have collaborated, with other researchers of the National Research Institute, on the development of systems of water harvesting fully mechanized (known worldwide as "Vallerani systems") and have recently developed a new semi-mechanized - based on Vallerani Systen and called "Agrfor" - for produce micro-basins with the active involvement of local rural communities.

After developing with our experts and in collaboration with the National Research Council, a system for water harvesting, we want to pass on our knowledge to the local community.In fact, particular attention was paid to the development of training courses aimed at increasing the level of communication and interconnection between the stakeholders and the community of local farmers.

The training in the areas of technological growth and research is a key tool for promoting sustainable development and therefore is a fundamental requirement of Agenda 21 (Declaration of Rio de Janeiro on sustainable development) that recognizes the importance of knowledge as a strategic resource for economic growth and social durable. The centrality of human capital is the key element of sustainable development, so it is necessary to improve access to all levels of education as the basis of sustainable development and social integration.

The institute has embraced the indications of the Rio Declaration and aims of the project the dissemination of knowledge.For this reason, this initiative offers a detailed training project for the improvement of human resources, to facilitate the acquisition of new knowledge and to integrate into daily activities results of technological development.The primary object of SAWaM-Pak then led in the development of more skilled human resources and provided a wealth of theoretical and practical criteria in respect of efficiency and autonomy, in the context of applied research that is technology transfer, which can strengthen the capacities of the autonomous territory to constitute a favorable environment for development.

Geopolitical context

In the areas covered by project there are highly conservative communities. These communities are strongly attached to their roots, to a system of values, cultures and traditions. This connection concerns not only the living but also the work and in our specific case: farming practices. It is important that the spread of technical knowledge is done in a respectful and non-invasive way. What we want to pursue is only a project for the dissemination of knowledge and technology in agriculture.

In fact, agricultural practices are still very backward: and transmit new knowledge is not a simple task, you must be patient, flexible, learn to relate to the community with whom we relate, respect the local traditions and social norms.But, equally necessary, is the involvement of influential people in the various communities, personalities who will themselves become a medium for the transmission of knowledge and to ensure cooperation and community participation in the project itself.

The training

In Italy our courses and activities are addressed not only to young graduates, but also to officials, people who already occupy roles of responsibility within public administrations. With our work we train them, upgrading their knowledge, their preparation: and the same way we do in Pakistan.Before developing a training plan, the Institute has studied especially the culture and traditions of Pakistan: identifying the specific social, features, trying to fully understand the needs of this country.

The training activities addressing the issue of social inclusion with the ultimate goal of improving the quality of life of some marginalized groups of children, such as the disabled, children and adolescents, who face different social problems.In addition, the role of women is certainly very significant in subsistence economies of Pakistan and then in agriculture. In this context, particularly important for the project to promote equal opportunities and the commitment to remove the starting conditions impediments to women's participation in the training proposal. The training provided by the project will contribute, therefore, to highlight the figure of women and to strengthen her role in the agricultural system in Pakistan.

The training activities are aimed at those who constitute the middle class but are structured to prepare the people, not only for the conduct of its activities, but also to form in turn young professionals.It is important e necessary to prepare people who play the role of facilities managers, who are not only able to do their jobs, but they are also able to train and manage subordinates.To ensure the continuity of the project we have created an educational system whose purpose is precisely the implementation of scientific and innovation skills of Pakistani institutions of higher education, in the various territories covered by the project.

Next to the system training, we also created some pilot structures, demonstrative but permanent, with the aim of putting in place a real transfer of knowledge and technologies to local communities. A practical way in our view to the creation, first of all, of new skills, but it was also able to sustain a continuous updating, this is why the pilot structures of the structures are permanent and not temporary.One of the long-term goals is also the formation of real educational districts that will become the driving force of local development can offer real opportunities to the younger generation of economic and civil growth.The project will increase the level of human capital of the three provinces of Pakistan involved, who are among the poorest and socially and politically unstable. In particular, they increased the technical and professional staff, whether in the public or non-governmental organizations, to promote and support the processes of social innovation in rural areas to support agricultural producers and their families.

Course participants will be chosen by the coordinator in agreement with the heads of the various project activities. The involvement in the project of numerous and qualified Italian and Pakistani partners will make submissions to the partners and to facilitate the selection of candidates considered likely to benefit from intensive training and guidance. In this regard, the project has worked and will work to promote the principle of equal opportunities in the education system proposed supporting the candidacies of women.

The continuity of the project will be guaranteed by an educational system that provides capacity building and scientific innovation of Pakistani institutions of higher education, the various areas subject of intervention, and by the installation of pilot demonstration structures to be used for permanent technology transfer to local communities, for the creation of new skills and an ability to updated. This will lead in time to the formation of real educational districts that will become the driving force of local development can offer real opportunities to the younger generation of economic and civil growth.

Provincial governments should promote innovation processes through the implementation of actions and policies to support small farmers in disadvantaged rural areas. The government must therefore increase investment in rural areas for the provision of public goods necessary to support innovative processes.The advocacy and the constant

support that the Ministry of Environment of the Federal Government of Pakistan provided to the project is strategic for its sustainability.

The synergies established with private partners, e.g. with the Roshan Citrus Farms, are another strong point for the sustainability of development activities during and after the end of the project. Thus, we can say that SAWaM-Pak responds concretely to the needs of education and training to overcome the problems caused by the obsolescence of knowledge and skills.

The aims

The project will yield benefits even more in the long run.This proposal seeks to meet the challenge of water scarcity, increasing scientific knowledge by promoting innovative solutions and technologies that can increase the productivity and efficiency of water use in agriculture and mitigate the impacts of increasing drought. Specifically, research will be conducted in the new techniques of water-saving irrigation, the rationalization of water use; of the methods of treatment of waste water for the recovery of useful substances; the mechanisms of resistance, response and adaptation to the level of species and communities; the development of strategies to combat biotic amplified by climate change; the selection of species / genotypes / local breeds of plants and animals that provide greater productivity in conditions of water scarcity. The overall objective is the promotion of water management in agriculture through a holistic approach, integrating scientific knowledge with the innovative agricultural techniques. The overall strategic objective is to contribute to increased production and food security even in compromised situations in terms of water availability in the context of local economic development.

It is essential that the systems of water management in agriculture are sustainable, so the new technical proposals will be implemented in collaboration with local communities to be integrated into farming systems compatible with the knowledge of farmers. The continuous training will be carried out through the activities of the various university institutes and research involved in the project and operating in different areas, including through the management of its permanent demonstrative structures.

The project will promote the development of agriculture in disadvantaged areas and in particular the development and stability of local agricultural markets, thus increasing both the availability and the access to food. In addition, it can be expected that rural communities, particularly those living on the margins of the desert areas, will be attracted by the innovations proposed for their simplicity and ability to implement them on their lands. If the developed technologies will be adopted successfully in these areas, they will certainly spread to the communities living nearby and from here to the semi-arid regions of Pakistan, thus improving the standard of living of a substantial part of the population of Pakistan. It should be emphasized that in the non-irrigated areas this development can take place without the need to request monetary support by the central government and / or large capital investments.

One of our most important aims is to create scientific and technological networks between industrialized and developing countries.The interaction with the community will be crucial to assess local needs and motivate their organization and participation. There will also be interactions with NGOs and government agencies and will be defined the guidelines and recommendations for the food industry, based on the results in the field, surveys and models, such as application tool for farmers to optimize the management of irrigation systems and other agronomic practices, improving production quality and efficiency of water use, as well as the selection of appropriate crops to the agricultural system.

The knowledge and skills of the project participants will be constantly increased through intensive training and guidance. In education and training, the project foresees synergies between all the recipients of the various tasks, where both horizontal and vertical, and a level of quality comparable to the activities of education and training that are already under way in Europe and in the world. The goal is to contribute to the formation of individuals with a wide scientific and technical knowledge that will enable them to work with competence in the field of water resources management and environmental sustainability. Equally important for the project will be the integration of scientific activities with policies of public awareness

Finally, we hope, through our work, to be able to ensure that technological advances offered reach the poorest farmers as effectively and efficiently as possible.This project is also important for the technical training that must be delivered in harmony with the cultural reality of the place. This is the goal that the Institute aims to achieve with the project SAWaM-Pak.

Recommendations

- More detailed identification of suitable areas for olive growing.
- Plant material: Selection of suitable certified cultivars (well-adapted with data) and production of good, healthy planting material.
- Training young plants properly as it determines the production of the tree.
- Apply right cultural practices (pruning, irrigation, fertilization, pest, and disease management).
- Proper irrigation system
  - -Irrigation scheduling (amount and time)
  - -Establishment of experiments (get data under your conditions)
  - -Transfer to farmers (training courses)
- Fertilization
  - -Soil analysis (N, P, K, B, Ca, Mg)
  - -Use fertigation
  - -Establish experiments for local cultivars and most adapted foreign ones
  - -Build up your data bank
  - -Transfer to farmers (training courses)
- Ensuring olive oil quality (harvesting, processing, marketing).
- Management of olive by-products and olive waste management.
- Prepare your human capital (researchers, agronomists, technicians).
- Train the farmers continuously
- Master plan for next 20 years with well-specified steps (to be evaluated at least every 3 years).

Concluding Address
by
Prof. Dr. Mukhtar Ahmed
Chairman, Higher Education Commission, Islamabad, Pakistan

I am very much pleased to be here among academicians, scientists and researchers and interact with distinguished scientists from Italy, Greece, Tunisia and Pakistan. It is a matter of honor for me to address the participants at the closing ceremony of the International Training Workshop on Sustainable Agriculture Water Management in a Changing Environment - ASpecial Focus on Olive Tree.Here, let me congratulate the Vice-Chancellor Professor Rai Niaz Ahmad and faculty and the Department of Environmental Sciences for organizing this training workshop for the very important issue of climate change, water and olive cultivation.

It is pleasant for me that the experts from various countries such as Italy, Greece and Tunisia, as well as from Pakistan attended this workshop and shared valuable experienceson olive, cultivation problems and management startgies to promote the crop in Pakistan. This is the need of time to demonstrate technologies for sustainable water use and promote olive cultivation in Pakistan in addition to providing technical expertise to local researchers, academia representatives and farmers.As in recommendations, it is proposed that the olive industry of Pakistan should be sustainable and profitable in order to compete in the international market. Moreover, the selection of suitable areas, olive varieties/cultivars, pest and disease management, ensuring quality control, preparing human capital and capacity building of farmers are some of the utmost factors for growing olive in Pakistan. The honorable expertalso pointed out that the present system of water management lacks to address the water challenges of Pakistan and suggested that effective improvement of water management in Pakistan is possible through the research, institutional partnership, and improved decision-making mechanism.

There is an absolute need for the implementation of olives research in the fields to meet the needs of the oiland getting maximum yields in a changing climate. Pakistan is blessed with vast natural resources,but facing a shortage of food, energy and water. New technologies must reachto farmers to increase per capita production in the country. The adoption of latest agricultural development and technology for olive production will help decrease food insecurity and billions of rupees spent on the import of edible oils. Training workshops can play a key role in improving olive production in Pakistan.

I am pleased to know that PMAS Arid Agricultural University Rawalpindi is already very actively working for the promotion of olive cultivation. The university should leadto address issues of olive production and submit a mega project to HEC. I assure you that HEC will support for the developmental initiatives of olive and its cultivation and holding such events on regular basis for the socio economic development of the region.

Ladies and Gentleman!

I hope that the training workshop should have added valuable information and technical assistance to trainees. Olive is of great interest for the people of Pakistan, as has been reported in noble way in many places in the Holy Qur'an. Once again, I would like to thank the dignitaries and experts from abroad and Pakistan and Vice Chancellor of Arid Agriculture University and his Team for giving me the opportunity to speak on this event.

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Pakistan Painda'abad

Workshop Highlights

INTERNATIONAL TRAINING WORKSHO
TAINABLE AGRICULTURE WATER MANAGEMENT IN A CHANGI
A SPECIAL FOCUS ON OLIVE TREE
30-October 02, 20
ized By:

ADMINISTRATION BLOCK

ILM
PAKISTAN
SHORT ABOUT US
SUSTAINABL
RKSHOP
ENVIRONMENT -

ILM PAKISTAN
SHORT ABOUT US

Thank you!

The Drylands

INTERNATIONAL TRAINING WORKSHOP
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AGRICULTURE UNIVERSITY RAWALPINDI
IVALSA

INTERNATIONAL TRAINING WORKSHOP
SUSTAINABLE AGRICULTURE WATER MANAGEMENT IN A
CHANGING ENVIRONMENT
A SPECIAL FOCUS ON OLIVE TREE
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