Food Security and Climate Change in Dry Areas

Abstracts

International Center for Agricultural Research in the Dry Areas (ICARDA)

P.O. Box 5466, Aleppo, Syria

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ICARDA

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Introduction

The dry areas of the developing world occupy some 3 billion hectares, and are home to one-third of the global population. About 16% of the population lives in chronic poverty, particularly in marginalized rainfed areas. Characterized by water scarcity, the dry areas are also challenged by rapid population growth, frequent droughts, high climatic variability, land degradation and desertification, and widespread poverty. Poverty and other social problems are leading to unsustainable agriculture, degradation of the natural resources and increased migration. Another major challenge is the impact of globalization, due to the changes in the world trade system and potential competition. This instability is further exacerbated by unrest in the financial markets. Food insecurity, poverty, and poor access to natural resources also manifest themselves in conflicts. Conflicts have been concentrated in regions heavily dependent on agriculture, destroying food and water supply sources, biodiversity and seed systems, and resulting in long-term negative effects on the environment.

Global climate change is a serious threat to the environment, natural resources, and production systems in dry areas. Current global median projections from the Intergovernmental Panel on Climate Change (IPCC) predict an increase in mean temperature and a decrease in mean annual rainfall in many of the already marginal dry areas. Such changes will result in lower river flows, increased evapotranspiration, greater terminal heat stress, drier soils, and shorter growing seasons; all of which would decrease agricultural productivity. Climatologists also predict more frequent climatic extremes such as longer droughts, more intense storm events and even extreme low temperatures that will damage or destroy crops and vegetation that are not adapted to these stresses. Both coastal and inland salinization risks are likely to increase, with even age-old natural aquifers being contaminated. There is a real possibility that some areas will become uninhabitable, and that some low-lying fertile areas will go out of cultivation.

The Stern Report (The Economics of Climate Change, 2006), calls for immediate action against global climate change, suggesting that the global economy will be reduced by 20% unless urgent action is taken. The threat to the dry areas is particularly acute, and there is a desperate need to develop not only technical options, but also policy and institutional options that improve livelihoods and increase food security under changing climates.

To address these issues, the International Center for Agricultural Research in the Dry Areas (ICARDA), with Jordan's National Center for Agricultural Research and Extension (NCARE) and other national, regional and international partners, has organized this International Conference on Food Security and Climate Change in Dry Areas, 1-4 February 2010, in Amman, Jordan.

The aims of the conference are:

- Sharing of views and experiences between national and international experts and other stakeholders on the urgent food security issues expected to be impacted by climate change.
- Identifying technologies, economic and policy options and priorities, to buffer climate change impacts through mitigation and adaptation and ecosystem resilience.
- Identifying effective modalities and mechanisms of cooperative partnerships between various national, regional and international institutes and organizations.
- Mobilizing human and financial resources to enhance regional and international cooperation, and to support research and development activities to cope with climate change.

The expected outputs of the conference include the establishment of an international network of key players, a synthesis of existing scientific knowledge and any gaps, a framework for supporting research, and the development of policy recommendations.

The conference covers the following five themes through invited keynote presentations in plenary sessions, and contributed papers presented orally in concurrent sessions or displayed as posters:

- Theme 1: Current status of climate change in the dry areas: simulations and scenarios available
- Theme 2: Impacts of climate change on natural resource availability (especially water), agricultural production systems and environmental degradation in dry areas
- Theme 3: Impacts of climate change on food security, livelihoods and poverty
- Theme 4: Mitigation, adaptation and ecosystem resilience strategies including natural resource management and crop improvement
- Theme 5: Policy options and institutional setups to ensure enabling environments to cope with climate change impacts

An abstract of all the presentations is given in this volume.

KEYNOTE

PLENARY

PRESENTATIONS

1.1. Impact of climate change on agriculture in dry areas

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Climate change will result in ecological degradation and further threaten the fragility of drylands, with serious consequences for crop and livestock production and food security. Drylands globally account for some 40% of the world's land area and over half of its rural population. Already a fifth of these areas have been damaged and degraded due to human activity and climate change impacts resulting in, for example, arable land lost to erosion, salinity, desertification, disappearing vegetation cover, loss of biodiversity and increasing water scarcity. There is an urgent need for comprehensive science-based assessments of the potential and limitations of agriculture in the drylands in the context of climate change impacts. Such assessments should include integrated social, environmental and economic issues at a range of spatial and temporal scales from global to regional to national to local. The latter is relevant as it is at the local level that provision of development resources, policy implementation and technical assistance will be critical to enable the population to sustainably adapt to the impacts of climate change. This paper presents a multi-scale integrated agro-ecological and socio-economic methodology and information system for a global to national assessment and management of sustainable agricultural development in the drylands and adaptation to climate change. The results of the impacts of various climate change scenarios on land productivity and water resources, food production, trade and food security, economic growth etc. for the Middle East and North Africa (MENA) region will be presented and discussed. An example of Qatar's country-lead food security and sustainable agricultural development strategy, policy making and integrated institutional development, covering the whole chain of the food system from production to consumption will be described. In Qatar, over 95% of the land area is desert and just 5% is arable in an environment of severe depletion and increasing salinity of ground water resources. The key issues here are related to development options to increase domestic self-sufficiency through solar desalinization and protected agriculture in combination with investments and trade that encompasses assured and secured food imports. The paper concludes with a discussion of a range of policy issues including, for example, food security and livelihoods, climate change mitigation and adaptation, protection of biodiversity, reclamation of drylands, increasing soil fertility and developing water resources, targeted agricultural research and technology development, regional and international development partnerships for protecting and sustainably developing drylands.

Keywords: drylands, ecological degradation, food security, MENA region, Qatar

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1.2. Ensuring food security in a changing climate: how can science and technology help?

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Dry areas face severe challenges, both biophysical and socioeconomic, to agriculture. These challenges are expected to become even more severe as a result of climate change, leading to more food insecurity and poverty. Today, an estimated one billion people face hunger and absolute poverty, and in many developing countries, the gap between food production and demand is increasing rapidly. Biophysical constraints to dry area agriculture include acute water scarcity, frequent drought, salinity, desertification and other forms of land degradation, and new climate change challenges such as changes in pest and disease distributions. Socio-economic factors include high population growth, poverty, weak institutions and lack of enabling policies contributing to unsustainable resource use, and related issues such as unemployment and rural out-migration.

These cannot be overcome without advanced technologies and innovative approaches requiring greater investment in agricultural research and political commitment to strengthen policies and institutions. Climate change is already impacting on agriculture and food security in dry areas. ICARDA and its partners use a three-pronged approach, aiming to enhance adaptation, mitigation and ecosystem resilience. The role of science and technology is illustrated through examples of successful technologies that have enhanced productivity in a changing environment. Improved varieties developed through conventional and biotechnology methods offer higher and more stable yields, resistance to multiple stresses, and prospects of adequate food supplies even in poor seasons. Over 900 improved varieties developed jointly by ICARDA and its partners are grown worldwide, generating net benefits estimated at US$850 million per year. Ongoing efforts aim to apply biotechnology tools and recombinant DNA techniques to develop the 'next generation' of varieties with better adaptation to climate change. New technology packages such as drought-tolerant wheat and barley, winter chickpea, and integrated pest management, have increased output and productivity and lowered production costs. Seed systems research has developed innovative models to disseminate new varieties tolerant to biotic and abiotic stresses. Modern scientific tools such as remote sensing and GIS are helping to refine and scale out traditional technologies such as rainwater harvesting, and significantly increase water productivity. Conservation agriculture technologies are helping to increase yields while protecting soil resources. Intensification and diversification of production systems, e.g. protected agriculture, introduction of high-value crops and value-added products, are creating new income and livelihood options. Rangeland and livestock research is helping to strengthen livestock production. Socio-economic research (impact studies, poverty mapping, value chain analysis, etc.) is helping to effectively target interventions and increase adoption and impact of research products. Ultimately, development requires partnerships. ICARDA's biggest strength is creating and facilitating partnerships between different institutions: national research systems, advanced research institutes, universities, NGOs, farmer groups, the private sector, regional and international development agencies, donors and others. These partnerships bring huge synergies that provide sustainable solutions to the problems of hunger and poverty in the world's dry areas.

Keywords: climate change, partnerships, modern scientific tools, research achievements, science and technology.

1.3. India's preparedness for food security in view of climate change

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In the likely event of enhanced adverse impacts of climate change on agriculture in arid and semi-arid regions of the world, where poverty is also concentrated, mitigation and adaptation strategies would demand far greater research and development effort, and financial, institutional and policy support. Frequent climatic extremes result in droughts, floods, migration and famines if food security is not at the centre stage of all-out actions on a long term sustainable basis. Continued high demographic pressure, unbalanced use of nutrients, low water use efficiency, soil erosion, degradation and poor health, changes in pest/disease patterns, etc. would further aggravate the situation. Climate change would considerably affect food availability and supply systems by direct and indirect effects on crops, livestock and fisheries, and on their inter relationships. With India's dependence on monsoon rains, Himalayan glacier-fed rivers and its long coastline, climate change would have a serious impact. Recent studies indicate a probability of 10-40% loss in crop production by 2080-2100 in India and other South Asian countries due to increases in temperature, rainfall variability, and decreases in irrigation water. The Indian Agricultural Research System accords high priority to understanding impacts of climate change, and developing adaptation and mitigation strategies,

and launched a nationwide climate change network involving 25 institutions. To prioritize research and development activities and develop an action plan for its implementation, India organized a National Conference on Climate Change in October 2007, highlighting additional strategies for increasing adaptive capacity, including bridging yield gaps, developing adverse climate tolerant genotypes and land use systems, assisting farmers in coping with current climatic risks by providing weather-linked value-added advisory services and crop/weather insurance, and improved land, fertilizer and water use management and policies. Agriculture will have to be insulated and be made more competitive, efficient, profitable, and develop inbuilt mechanisms to reduce its vulnerability. Evolving scientific, technological, economic and political solutions to address these challenges is in the interest of agriculture as well as the global environment. There is an appreciation of the urgent need to strengthen locally relevant research efforts in the vulnerable regions, to understand the probable biophysical and economic impacts of, and adaptation to, increasing climatic risks, especially in relation to subsistence agriculture and native foods such as millets, legumes, oilseeds, and local species of fish and livestock. Efforts are on to evolve new and innovative models of cooperation and partnerships for adaptation research and development, including input-intensive research with long gestation periods needing highly specialized human resources with innovative institutional setups and partnership mechanisms, requiring action and added investment in agriculture, human resource development and extension. It is believed that transgenic culture in agriculture would be a major savior, hence, ongoing efforts in gene discovery, allele mining and contemplated efforts of their effective deployment in appropriate genetic backgrounds are considered vital. After a series of discussions, region by region, season by season, situation by situation and system by system, research initiatives are being taken.

Keywords: adaptive and mitigation research, food security, India national climate change network, human resource development, use of transgenics in agriculture.

1.4. Impact of climate change on drought in dry areas

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Drought is an insidious natural hazard that results from a deficiency of precipitation from expected or ‘normal’ that, when this deficiency is extended over a season or longer period of time, is insufficient to meet the demands of human activities and the environment. Drought is a temporary aberration, unlike aridity, which is a permanent feature of the climate. Seasonal aridity (i.e. a well-defined dry season), an important feature of the climate of many dry areas, also needs to be distinguished from drought. Drought and aridity are often confused or used interchangeably. The differences between these terms need to be understood and properly incorporated in drought monitoring and early warning systems and preparedness plans. Drought risk is best defined by a region’s exposure to the hazard, and societal vulnerability to that hazard. Changes in climate and climate variability due to anthropogenic factors is projected to result in greater exposure to drought through an increase in the frequency, severity, and duration of drought events for many already drought-prone regions. Societal changes such as a rapidly expanding population suggest the risks associated with drought in many dry areas will increase because of added pressures on already scarce water and other natural resources. As a result, vulnerability to drought will increase along with the prevalence of water scarcity even during period of normal precipitation. Projected increases in temperature and concomitant increases in evapotranspiration rates will result in even greater climate change impacts. These changes will undoubtedly have significant impacts on food security in many countries. This paper will conclude with a call for action to develop national drought mitigation strategies that include comprehensive drought monitoring and early warning systems, appropriate impact assessment methods and mitigation strategies to lessen future impacts, and national drought policies that promote a more pro-active approach to drought

management. The development of a successful strategy will require coordination of activities between the various ministries and a broad range of non-governmental organizations, universities, and other stakeholders. To be successful, this strategy must draw from the experiences of other regional and international centers of excellence on drought, climate change, and food security. Donor support will be necessary to support development and implementation of many aspects of a national drought strategy in many countries. The goal of this national drought strategy is to adopt a more proactive, risk-based approach to drought management. Improved drought preparedness today will help many countries improve their resilience to future drought events and lessen the impacts of these events on food security.

Keywords: aridity, climate change vulnerability, drought management strategies, national plans.

1.5. Changes in extreme climate events and their management in India

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High anthropogenic production of greenhouse gases and associated changes in climate is being looked upon as a great challenge to food and livelihood security in India. Frequency and intensity of chaotic weather events like late/early onset of rains, late or early withdrawal, long dry spells, droughts, floods, cold/heat waves, cyclones, hailstorms, etc., have increased due to global warming. Himalayan glaciers are retreating at rates of 12-24 m per annum. About 28% of the geographical area of India is vulnerable to droughts, 12% to floods and 8% to cyclones. India has evolved appropriate policies and institutions, enacted/amended laws, set up authorities, and committed financial resources for immediate relief, adaptations, mitigation (resilience) and reducing vulnerability to climatic changes. As a case study, crop contingency plans, compensatory production systems and safety nets to manage chaotic climatic changes have been illustrated for the droughts in 2009. Medium and long term measures are in place for the *in situ* conservation of rainwater, variety/crop diversification, developing and recharging ground water, enhancing efficiency of surface water resources, breeding tolerant crops, varieties, trees and animal breeds to offset vulnerability. Safety nets like insurance, credit, employment, buffer food stocks, public distribution of food grains, fodder, feed and seed banks are described. Deployment of energy to extract ground water by farmers was the latest unique feature of managing droughts in India.

Keywords: adaptation and mitigation strategies, drought, extreme climatic events, food and livelihood security.

1.6. Achieving 'more crop per drop' in a changing environment

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Everywhere in the dry areas, people are worried about increasing water scarcity and its implications on food security, especially with climate change. Concerns over future food security of developing countries are justified as the water share of agriculture will certainly decline due to rapidly growing populations and diversions to higher priority non agricultural sectors. With less water projected for agriculture, more food is needed to feed growing populations where delicate tradeoffs are required to sustain productive agro-ecosystems. While almost everything else is rapidly changing, agricultural water management is not. Unless a change is made in how we manage agriculture and its water use, a decline in productivity and deterioration of the resource base is certain. Countries are challenged to implement new policies that will bring about a shift in the way they value and use scarce water resources in agriculture. As

more food should be produced with less water, ‘more crop per drop’, i.e. a shift in focus from ‘land productivity’ to ‘water productivity’, is necessary in water limited areas. This means the increase of biophysical, economic, social and/or environmental returns from a unit volume of water. Increasing water productivity requires changing cropping patters, irrigation schedules, crop varieties, etc. Many technological options are available to increase water productivity, such as deficit irrigation for fully irrigated areas, supplemental irrigation in rainfed systems, and water harvesting for rangeland agro-ecosystems. Rethinking current water and agricultural practices is necessary if the food security of countries in dry areas is to be sustained or enhanced. A change in the policies of water valuation and allocation together with institutional setups is necessary to create enabling environments for the required change.

Keywords: climate change, water productivity, deficit irrigation, supplemental irrigation, water harvesting.

1.7. Impacts of climate change on food security and livelihoods

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Developing countries are projected to be hard hit by climate change, particularly in South Asia and sub-Saharan Africa. Many developing countries are highly dependent on agriculture for food security, and as source of livelihood and economic growth in rural areas. To estimate the impacts of climate change on agriculture, the International Food Policy Research Institute has assessed the impacts on production of major cereal commodities under a number of climate change scenarios and General Circulation Models (GCMs). Using the National Center for Agricultural Research GCM, and the A2 climate change scenario from the Intergovernmental Panel on Climate Change, it is projected that global wheat production would be reduced by 47%, rice by 27% and maize by 13% in 2050 under irrigated conditions compared to a no-climate change scenario. Rainfed production is estimated to fall by 28% for wheat, 16% for maize, and 13% for rice in 2050 compared to a no-climate change scenario. Lower production boosts food prices compared to the no-climate change scenario, reducing projected calorie consumption by 22% in developing countries in 2050 compared to the no-climate change scenario, and causing projected child malnutrition to rise by 21%. These impacts would significantly worsen food security, especially for the poor and vulnerable groups in rural communities. Critical policy reforms and agricultural adaptation funding are required for all countries in the developing world. Investments in agricultural research, irrigation and water use efficiency, and rural roads, need to be increased substantially to counteract the effects of climate change.

Keywords: cereal production under changing climate, General Circulation Model, food security, investment in research and infrastructure.

1.8. Applying a broadened genetic base in crop breeding

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Given that climate change is a virtual certainty, how it will affect food production in specific places is uncertain. How plant breeders and scientists may continue to produce crop varieties to meet these uncertainties is a great challenge. Fortunately, we have many tools to apply to the problem, some of them very old and reliable, but also many new tools are ready or nearly ready for application to the new challenges. Two issues must be addressed: the availability of genetic resources and the predictability of conditions in the targeted environments. We have a solid conceptual basis for genetic resources that may be applied, tracing to the genepool concept of J.R. Harlan and others. This concept embraces the primary gene pool

(infraspecific gene resources), secondary gene pool (interspecific gene resources), tertiary gene pool (intergeneric gene pool), and synthetic gene pool (synthesized or modified gene resources). The scientific basis for characterizing these gene pools is widely understood and many examples of their uses are extant, except for the synthetic gene pool which is in its infancy and is the subject of intensive study and development at the molecular level. At the other extreme is the concept of adaptation, a genetic concept that refers to the genetic architecture of plants that permits them to thrive under specific environmental conditions or under a wide range of conditions. Specific and general adaptation are very important concepts that must be addressed by plant breeders and ultimately by agronomists who will discover the factors affecting the performance of a crop and particular crop varieties. Two conceptually exclusive concepts of plant breeding may be applied: analytic and empirical. The analytic approach is favored as a way to gain good understanding of how genes work and the conditions under which performance is optimized. To support the analytical approach, modern methods for environmental characterization may be employed, such as GIS techniques that can aid in assessing the probabilities of certain climatic events. However, without in-depth genetic and environmental understanding, the empirical approach, taken by the earliest farmers and many current plant breeders, is based on plant populations with high variability and subjecting them to the environmental conditions of the target environments. Very successful landraces emerged over many centuries by the empirical methods. Clearly, a combination of the two approaches has great merit. Success can only be assured if good evaluation methods are used, both at the genotypic and phenotypic levels in the field. The concept of selection and how selection may be applied efficiently is one of the main challenges for plant breeders who apply the genepool concept at any level. Simple examples are given with wheat and maize to illustrate the plant breeding options available to assure food security in changing environments.

Keywords: adaptation, climate change, gene pool, plant breeding concepts.

1.9. Genetic resources, climate change and the future of food production

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Climate change is impacting agriculture in a plethora of ways, some of which are less immediately visible than others. The diversity contained within plant genetic resources provides the variability needed for adaptation, and therefore will serve as a key element in maintaining food production under novel temperature, precipitation, and pest and disease conditions. This diversity is increasingly threatened, and there is an urgent need to collect and secure plant genetic resources for agriculture for the global community. Likewise, the use of these resources in order both to mitigate, and to adapt to, climate change, must be increased in order to proactively address the needs of agriculture, requiring a coordinated effort from international, regional, national and local stakeholders. Countries are interdependent regarding genetic resources for food production, and the political framework exists to share and use these resources for efficient use under climate change. The Global Crop Diversity Trust and its partners worldwide are working to prepare for and address climate change through collecting, securing, improving the management of, researching on, and using plant genetic resources.

Keywords: climate change, diversity, food production, plant genetic resources.

1.10. Adaptation to climate change in Africa – the experience of Ethiopia

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Many elements of human society and the environment are sensitive to climate variability and change. Human health, agriculture, natural ecosystems, coastal areas, and heating and cooling requirements are examples of climate-sensitive systems. Many professionals now widely agree on the fact that human activities are disturbing the fragile climatic equilibrium of the earth. When this equilibrium is affected, the composition of the global atmosphere changes which can impact economic, social and cultural aspects of human beings. At present, climate change is evidenced by increased atmospheric temperature, which is just one of the many indicators for the ongoing changes. Other indicators are increased frequency and severity of drought and storms, and a rise in sea level. These changes are significantly affecting the lives and livelihoods of many people in Africa, especially poor farming communities that are dependent on rainfed agriculture. Several initiatives and actions are being attempted, to better withstand the impacts of climate change as adaptation strategies. Potential adaptation measures are being tried in Africa in general, and in Ethiopia in particular. This paper gives details of the adaptation efforts made in managing the impacts of climate related stresses in Africa with special emphasis on the experience of Ethiopia, such as establishing adaptation related resource management programs, developing guidelines, physical capacity building, establishing knowledge banks, networking and practical training. Global temperature is expected to rise as human activities continue to add carbon dioxide, methane, nitrous oxide and other greenhouse gases to the atmosphere, which could create further changes in climatic patterns that will affect agriculture, fisheries and tourism in Africa.

Keywords: adaptation strategies, climate change, rainfed agriculture, Ethiopia.

1.11. Policy and institutional approaches for coping with the impact of climate change on food security in the dry areas of the CWANA region

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Given its predominantly dry climate and limited irrigation potential, the Middle East and North Africa (MENA) region is unable to produce enough cereals to meet its own demand. On average, the region imports about 40 million tonnes per year, and even without climate change, this was projected to reach 70 million tonnes per year by 2020. Cereal imports seem likely to grow even more with climate change, because of lower rainfall and lower yields in dry areas, reduced river flows to feed irrigation systems, and even higher levels of variability in seasonal rainfall with more frequent and more severe droughts. Globally, climate change is likely to contribute to higher and more variable world cereal prices, with a greater probability of sharp import price spikes in some years. Within this emerging context, ensuring food security in the Central and West Asia and North Africa (CWANA) region will require that governments give high priority to policies and investments that: (a) help farmers adapt their agricultural systems to changing climate conditions, (b) strengthen national capacities to manage droughts and production shortfalls, and (c) provide effective safety nets for the poor against droughts and price spikes. Many of the past policies adopted in the CWANA region to address these issues have proved costly to governments, have benefited large farmers and herders at the expense of the rural poor, and have encouraged unsustainable farming practices. In the future, more cost effective interventions will be needed that are more carefully targeted to the needy, less distorting of market and producer incentives, and more environmentally benign. This paper discusses important lessons from past policy approaches in the CWANA region and develops criteria for guiding future policy and institutional choices. Particular attention is given to managing droughts and price spikes, and it is argued that while the public sector still has important roles to play, market assisted approaches, such as weather index insurance, should be more widely adopted.

Keywords: cereal imports, CWANA region, MENA region, policy and institutional changes, price spikes, weather index insurance.

1.12. Rethinking agricultural development of drylands: challenges of climatic changes

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Drylands cover more than 40% of the global land area and are the home to nearly a third of the global population, 90% of who live in developing countries. In the 21st century, agriculture remains fundamental for poverty reduction, economic growth and environmental sustainability. Land resources have a primary role in providing food and fiber for increasing population, particularly in the rainfed areas which account for 82% of total area. Moreover, 75% of the world's poor are rural and most are involved in farming. Development of drylands faces several challenges, and climatic change and increasing land degradation are the most serious threats affecting their resource functions. Additional challenges include; (a) increasing needs for food production to meet the demand of increasing population, (b) low productivity, (c) vulnerability of local population, (d) shifting of land from food to bio-fuel production, (e) increasing cost of energy, (f) shortage of water resources, (g) impact of globalization and market liberalization, (h) poor governance and lack of sustained strategies, (i) lack of skilled human resources and poor research capability, (j) increasing forced migration, and (k) marginalization of rural inhabitants. Although global climatic changes are unequivocally occurring and are having global impacts, many scientists raise concerns about uncertainties regarding the future projected impacts resulting from, or associated with, global warming. Some of the uncertainties are scientifically based, while others are related to scaling down of global warming impacts to the regional and local scale. Another issue, not globally addressed so far, is the impact of long term climatic changes, which had started long ago and which marked the beginning of the global warming. Local climatic changes or long-term climatic variation had profound impact on the dryland resources. In many cases, it was not separated from the impact of global warming, and was not given proper attention due to lack of regional systematic assessments based on quantitative data. The uncertainties associated with future threats caused by global warming, the inability to identify its impacts at the regional and local level, and the threats of local land degradation associated with long-term land degradation, are among the challenges planners and decision makers have to face in selecting the best approaches and strategies to protect dryland resources. Development has site specific requirements, and implementation has to consider local as well as regional and global drivers. At the same time, decision makers and planner have to deal with many interrelated issues when dealing with the impacts of global warming and land degradation. Adaptation of dryland farming systems to address these global, regional, and local challenges will require fresh approaches related to new policies, and governance, research, and technological tools. This presentation addresses the impacts and future threats inflicted by global warming and land degradation on dryland resources, with special focus on the Mediterranean regions. Fresh approaches, new opportunities, paths of development, strategies, research, and modern technological tools needed to adapt to, or mitigate the impacts of global warming and land degradation on drylands resources will be discussed. It is to be noted, that although agricultural development is an important part of the solutions to many threats caused by different drivers, solutions coming from non-agricultural sectors are as important as well.

Keywords: agriculture development, climate change adaptation and mitigation, dryland farming, land resource degradation, policy and institutional options.

1.13. Faba bean and its importance in food security in the developing countries

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A very old domesticated crop plant, *Vicia faba* has received many names which should be a proof of it being a well known crop in the Old World. It has been used both for animal and human consumption, as well as for improving soil fertility as a green manure crop. The whole plant can be used. It is still a basic staple in the diets of people in several countries. Its value as a food and feed crop lies in its high lysine-rich protein and carbohydrate contents. The negative correlation between yield and protein content, common in cereals and some grain legumes, is not there or very low in faba bean, enabling the crop breeders to increase the protein content without reducing the yield. Besides being a perfect complement to cereals in the diets of people from most ancient times, faba bean has also been an excellent component of crop rotations, something that has been very much neglected in modern cropping, at a time when there is an urgent need to reduce the use of nitrogen fertilizers because of environmental concerns, particularly because of their contribution to greenhouse gas emissions. In spite of its merits, the world cultivated area of faba bean has decreased in the last 50 years. China is the leading producer, followed by Ethiopia, Egypt and France. For green pods and seeds, Bolivia and Algeria are the countries with the largest area, but China and Morocco are the highest producers. Crop improvement efforts in the past have helped resolve some of the classical constraints, although the spread of valuable forms has not been as successful as required. The genetic aspects of non-nutritional (formerly called 'anti-nutritional') factors such as tannins, vicine and convicine, phytates, are now well understood and useful markers are available. Several sources of resistance to the most common diseases (chocolate spot, ascochyta, rust, and broomrape) are known and transferred to valuable commercial cultivars. Viral and bacterial diseases do not constrain production as much as the other mentioned diseases. Stem nematode as well as traditional legume pests such as bruchids and sitona weevil still need to be evaluated. The production potential of faba bean is still to be fully harnessed. Its yield could easily be doubled in most regions, as shown by the performance of modern improved cultivars grown with appropriate agronomic management. New determinate forms have been registered, allowing for mechanical harvesting. Even when crosses with other species have been impossible, there is a potential to transfer desirable traits from diverse sources through the possibilities opened by new biotechnologies. Transformation and in vitro regeneration has been demonstrated allowing the circumventing of cross sterility. Recent information from the model species *Medicago truncatula* is greatly facilitating genetic characterization and comparative mapping of traditional legume crops including faba bean, that may bring some new perspectives to faba bean breeding efforts. While waiting for the perfection of new research approaches, using traditional plant breeding protocols and marker assisted selection (MAS) for disease resistance and quality traits can be the best approach for obtaining the desired materials in a shorter time in most countries.

Keywords: disease and pest resistance, genetic characterization, molecular markers, non-nutritional factors, protein content, role in feed and food, traditional breeding.

1.14. The Green Morocco Plan in relation to food security and climate change

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More than 78 % of the surface area of Morocco is arid or semi-arid, and the country is located in one of the most vulnerable regions of the world with respect to the impact of climate change. It is estimated that because of climate change, the proportion of the total land suitable for agricultural production in Morocco will be reduced to 8% at the end of the 21st century, as compared to 12% at present. The challenge is to produce more food of good quality in even drier conditions. This is the objective of the Green Morocco Plan (GMP), the new agricultural development strategy of Morocco. The GMP is based on six core ideas; (i) a clear conviction that agriculture is a main catalyst for growth to combat poverty, (ii) all-inclusive agricultural sector, but differentiated strategies depending on target producers, (iii) address the underlying problem relating to producers, especially innovative aggregation models which are socially just and adapted to each sub-sector, (iv) investment in the agricultural sector, (v) adoption of a pragmatic, transactional approach with 1000 to 1500 practical development projects, and (vi) no sub-sector to be neglected and the provision of a liberalized market environment to boost growth potential. The reform strategy is built around two pillars, making agriculture a major catalyst for economic and social progress with a clear recognition of sustainable development principles. Pillar 1 deals with the development of a modern agricultural sector based on private sector investment in high productivity/high value added sub-sectors, and pillar 2 concerns the modernization of production with a social impact, using public investment in social initiatives to combat rural poverty. Implementation should take into consideration several transverse problems in order to improve agricultural productivity, especially issues related to land tenure, water scarcity, inter-professional organizations, free-trade agreements, and business and administrative refocus. While the modern agricultural system is based on providing big farmers preference in securing an important part of the domestic consumption and most of the agricultural export, the GMP gives the agriculture of small farmers, special attention. That is way the social offer of Morocco is considered as a unique proposal, providing a diverse portfolio of pre-packaged practical projects having the potential for huge impact, ensuring accessibility to leading social-development financial institutions at ground level, and establishing genuine long-term partnerships with farmer associations and representatives. The GMP is both an opportunity and a big challenge for the national agricultural research system. Researchers should work to reduce gaps in productivity and product quality to ensure sustainability of agricultural systems in the dry areas. The contribution of agricultural science and technology, in the climate change context, in meeting the ambitious, but feasible, objectives of the GMP, is strategically of great significance.

Keywords: agriculture development strategy, drylands, land suitability, research for development, social institutions.

1.15. Addressing concerns of climate change and food security in the Asia-Pacific region

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Agriculture remains important for the economic growth, livelihood and sustenance of the majority of the people in the Asia-Pacific region, which contains about 57% and 73% of the world's total and agricultural population, respectively. The land availability per person is only about one fifth of that in the rest of the world. Research in the agricultural sector led to remarkable achievements in the past to attain food security and reduction in poverty. The agricultural population is dominated by smallholder farmers, pastoralists, tribal people, fishermen and agricultural laborers. However, about 63% (640 million) of the world's hungry and malnourished, 50% (over 660 million) of the world's extreme poor (living on less than US$1/day), and 70% of the world's undernourished children and women, live in the Asia-Pacific region. Over the last two years, the number of hungry in the region has increased by about 11%. The Millennium Development Goals, especially to reduce hunger and poverty to half by 2015, are no longer closer to being achieved, despite all the commitments and on-going efforts. The region is facing stagnation or slow down of productivity growth rates, soaring food prices,

increasing energy costs, diversion of land area for biofuel production, consequences of climate change, and economic shocks. The problems of the numerous and geographically dispersed smallholder farmers and other resource poor communities, who form the bulk of the agricultural population, persist: low yields, low returns from farming, and inadequate access to resources and markets. Natural resources, particularly land and water, are becoming scarcer and more degraded. In addition, the impact of climate change on food security is now a real concern. Addressing these complex challenges, with opportunities to harness new innovations, will now require 'out of the box' solutions (technology, institutions, policies, and higher investment). Previous analyses have unequivocally shown that investments in agricultural research had high rates of return both in terms of growth and poverty reduction in the region. The Asia-Pacific Association of Agricultural Research Institutions (APAARI), being a neutral forum to foster partnership among major research institutions (NARS, CG Centers, ARIs and other regional fora) in the region, has recently revisited agricultural research priorities to address the specific concerns regarding climate change and food security, by holding two expert consultations involving key stakeholders. As a result, the 'Tsukuba Declaration' on climate change and the 'Bangkok Declaration' on agricultural research for development (AR4D), have clearly drawn up a road map for the future reorientation of agricultural research for inclusive growth and development, as well as ensuring large scale impact on poverty and hunger. Highlights and recommendations of both expert consultations and the proposed strategy are presented in this paper, by drawing a parallel to the drylands of South, West and Central Asia.

Keywords: agriculture research for development (AR4D), Asia-Pacific region, climate change, poverty alleviation, investment in research.

CONCURRENT

SESSION

PRESENTATIONS

Theme 1: Current status of climate change in the dry areas: simulations and scenarios available

Theme 2: Impacts of climate change on natural resource availability (especially water), agricultural production systems and environmental degradation in dry areas

Theme 3: Impacts of climate change on food security, livelihoods and poverty

Theme 4: Mitigation, adaptation and ecosystem resilience strategies including natural resource management and crop improvement

Theme 5: Policy options and institutional setups to ensure enabling environments to cope with climate change impacts

2.1.1. Analysis of Jordan's vegetation cover dynamics using MODIS/NDVI from 2000-2009

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Jordan has been affected by frequent droughts in the last few years. A Moderate Resolution Imaging Spectroradiometer (MODIS) - Normalized Difference Vegetation Index (NDVI), time series 2000-2009, 1 km resolution was used to extract the NDVI values of a 10 km buffer area for twelve meteorological stations representing the rainfed cultivated areas of Jordan. The objective of this study was to investigate the vegetation dynamics within seasons, and stations, as an indication of climate change. The average annual NDVI values for the different stations tend to follow a similar pattern through the growing season, which extends from November to May. It reflects that there is decrease of precipitation from west to east and from north to south. Results of Pearson correlation analysis showed a significant response of monthly NDVI to cumulative rainfall. A threshold method was developed to determine the onset and the end of the growing season. Results show that in the past four years, a trend of delay in the start of the growing season is occurring, especially in the south of Jordan.

Keywords: climate change, Jordan, MODIS, NDVI, remote sensing.

2.1.2. Application of the IHACRES rainfall-runoff model in semi-arid areas of Jordan

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With increasing demands on water resources in Jordan, application of rainfall-runoff models can be part of the solution to manage and sustain the water sector. The change of arid climates is considered as one of major factors affecting the rainfall-runoff relationships. This paper presents the preliminary results of applying lumped rainfall runoff models into ephemeral streams in northeastern Jordan where rainfall can exhibit a rapid change in intensity and volume over relatively short distances. The IHACRES model (Identification of unit Hydrographs And Component flows from Rainfall, Evaporation and Stream-flow data) can confidently be applied in semi-arid catchments, and under different hydro-climatic zones and time steps. The major problem with this application is the limitation of long term continuous observations. However, the results of this study showed a good agreement between effective rainfall and stream-flow. Therefore, this model can be used to predict water flow for which there are no existing records. Furthermore, because of the complexity of climate attributes in the region, there are often errors in runoff estimations.

Keywords: effective rainfall, IHACRES, semi-arid areas, Unit Hydrograph.

2.1.3. Generating a high-resolution climate raster dataset for climate change impact assessment in Central Asia and northwest China

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The contiguous dryland region of Central Asia and northwest China is expected to be significantly affected by climate change. In a pivotal and very diverse region, where the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report predicts a precipitation increase or decrease depending on the specific location, the coarse-resolution climate change maps provided by Global Circulation Models (GCM) are unable to

capture the influence of high-intensity relief. The paper describes the steps taken for generating high-resolution (1 km) maps of future climates in the five countries of Central Asia and the Chinese province Xingjiang. Three different time horizons (2010-2040, 2040-2070 and 2070-2100) and four climatic variables (precipitation, minimum, maximum and mean temperature) were downscaled to high-resolution gridded datasets based on 17 out of the 23 GCM outputs under three greenhouse gas emission (SRES) scenarios (A1b, A2 and B1). The downscaling method consisted of overlaying coarse-gridded CGM change fields onto current high-resolution climate grids. By automating the map generating process in a GIS environment, 5184 high-resolution maps of future climatic conditions were generated for this dryland region. These maps confirm agreement of the selected GCMs on a significant warming (from approximately +2°C to +5°C by the end of the 21st century) over the whole area, but major disagreement between models on the direction and extent of precipitation changes. The downscaled maps will be aggregated and used for analyzing climate change impacts through changes in agroclimatic zones, growing periods and crop suitability.

Keywords: Central Asia, China, climate change, precipitation, temperature.

2.1.4. Mapping drought extent, severity and trends using the Standardized Precipitation Index

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The Standardized Precipitation Index (SPI) is a tool for monitoring drought and anomalously wet events, based on a cumulative probability distribution of precipitation time series. Using a time series of monthly precipitation data from Sudan, the annual SPI has been calculated from 1921 to 1993, a period in which the number of meteorological stations in the country expanded from 50 to 120, and declined afterwards to 30. By interpolating station SPI values and using a mask to cover hyper-arid areas, 73 annual SPI maps were created which allow the characterization of historical drought patterns, and the comparison of the extent of drought in the different states of Sudan. The Drought Extent Index, defined as the average percentage area that would be affected by drought each year, varies between states between 5% and 11%. This is a surprisingly narrow range, indicating that drought is a feature of all states, with Southern Darfur and Western Darfur the most vulnerable ones. The SPI trend analysis indicates that droughts became both more extensive and more severe towards the end of the period, and that wetness anomalies have declined. Droughts during the mid-1920s, particularly in southern Sudan, were followed between 1930 and 1960 by a period characterized by normal or even above normal precipitation across the country, interrupted by local and scattered drought events. This period of relative climatic stability was followed by an increase in droughts during the 1960s and 1970s, and culminated in a new climate state characterized by multi-year regional droughts from 1982 onwards. The drought patterns of the period 1921 to 1993 are indicative of the increases in precipitation variability to be expected under global warming. The SPI mapping is in agreement with field and satellite data and can be a useful tool for comparing longer-term vulnerability to drought within countries.

Keywords: Sudan, Standardized Precipitation Index, drought.

2.1.5. Trend analysis for rainfall and temperatures in three locations in Jordan

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Major challenges that face global agriculture are climate change and shortage of water. The impact of climate change combined with the shortage in water will adversely affect agriculture in Jordan. Agriculture in Jordan was one of the important sectors of the national economy during 1960s. During the last 20 years, its importance has declined due to many factors, including drought occurrence and poor rainy seasons. A linear trend analysis (series data) for rainfall and mean maximum temperatures in three locations in Jordan (Irbid, Amman and Raba) was applied using a base line for 30 years (1976 to 2005), to forecast and project rainfall and maximum temperatures for 20 years (2006 to 2025). The rainfall trend showed a decrease at rates of 1.8, 1.4 and 1.6 mm per year in Irbid, Amman and Raba, respectively, and maximum temperatures showed an increase by 0.04ºC per year. The present study showed the danger and adverse impact of climate change on crop production in Jordan. Consequently, new measures and agricultural practices should be taken to mitigate these concerns.

Keywords: Linear Trend analysis, rainfall, temperature, climate change.

2.1.6. Fluctuations of maximum temperature in Sudan during 1951-2004

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In recent years, a change in climate has been documented in many locations throughout the world, and yet temperature is one of the most important indicators of changes in dynamic and radiative processes in the atmosphere. In this study, we investigated the long-term trend of mean annual maximum temperature at 19 synoptic stations in Sudan (five stations in desert climates (BW), 10 stations in steppe climates (BS), and four stations in tropical climates, based on the Koppen climatic division), with a minimum record of 53 years. For the analysis, we used the Mann-Kendall test, low pass filtering, and Autocorrelation Spectral Analysis. Increasing and decreasing surface maximum temperature trends were found. We also found inter-decadal variations in surface maximum temperature. During the 1970s, the mean annual maximum temperature series exhibited warming, but this warming was not uniform, continuous, or of the same order of magnitude at all the stations. For mean maximum temperature, positive trends were shown from 1951 to 2004 and from 1976 to 2004 at most stations. The results of the Autocorrelation Spectral Analysis (Periodicity) for the mean annual maximum temperature showed that the quasi-biennial oscillation (QBO) exists at most stations during both increasing and decreasing trends.

Keywords: Sudan, Autocorrelation Spectral Analysis (ASA), Mann-Kendall method, periodicities, surface air temperature.

2.1.7. Monitoring the vegetation dynamics as a response to climatic changes in the eastern Mediterranean region using long-term AVHRR/NDVI and LANDSAT images

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Climatic variability and drought periods affect the pattern of vegetation growth and agriculture production, particularly in dryland regions. In the past decade, these phenomena have attracted special attention in the eastern Mediterranean region because they affect differently the economy, agriculture and society as a whole. High temporal resolution remote sensing data are required in order to discriminate between short and long term trends in surface features, as indicators of enduring environmental pressure. Time series analysis is able to detect the tendencies of development in terms of changes in vegetation abundance (e.g. NDVI). Inter-annual climatic changes such as temperature and precipitation profoundly influence plant phenological status such as the onset of growth, the rate of biomass accumulation, and the onset and rate of vegetation senescence. The present study addresses long-term variation in vegetation cover in response to climatic variability and changes in Jordan. The analysis is based on monthly 1 km AVHRR/NDVI and LANDSAT TM data. Trend analysis was applied using two non-parametric methods, the Modified Seasonal Kendal test and the Kendall slope. The inclination and significance of long-term trends in vegetation abundances were used as indicators for monitoring vegetation response to climatic conditions. Additionally, shifts in the phase spectra and results from continuous wavelet transform gave important evidence about changes in vegetation and land cover. The obtained results show that the changes in vegetation were highly related to the climatic conditions as well as to geo-physical, socio-economic and political factors.

Keywords: climate change, vegetation dynamic, trend analysis, satellite images, Jordan.

2.2.1. A land suitability study under current and climate change scenarios in KRB, Iran

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The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) predicts that an increase in mean temperature and a decrease in mean annual rainfall will most likely amplify. Such changes will affect not only crops but also land suitability. Assessing the suitability of an area for crop production requires a considerable effort in terms of information collection that presents both opportunities and limitations to decision-makers. In this study, a GIS based method has been used to match land suitability for winter wheat production, based on the biological requirements of the crop and the quality and characteristics of land within the Karkheh River Basin (KRB), Iran. Overall suitability is recognized by the Most Limiting Factor method (MLF), in preference to a weighted GIS model which scores attributes. The results showed that under current climate condition 8.7%, 7.6% and 28% of the area, respectively, is 'highly', 'moderately' and 'marginally' suitable for winter wheat production, and the remaining 55.7% is unsuitable. Under climate change scenarios, the suitability of land for winter wheat showed considerable variation. With increased temperature and precipitation, 'highly and moderately suitable' areas increased, but with decreased precipitation, 'highly suitable' areas decreased by as much as 91%. This methodology could readily be adapted and developed for other soil and climatic conditions.

Keywords: Iran, climate change, Karkheh River Basin (KRB), land suitability, Most Limiting Factor method (MLF), winter wheat.

2.2.2. Coping with precipitation variability and soil moisture stress for agricultural productivity in the rain-fed foothill region of the northwest Himalayas

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The foothills of the northwest Himalayas, covering an area of 2.14 million hectares, represent the most fragile ecosystem of the Himalayan mountain range because of their peculiar geological formations. About 12% of the total area of Jammu region, and about 10% of the area of Punjab state, constitute a dry semi-hilly belt. The lower foothill area has a semi-arid or sub-humid climate. The agricultural productivity levels of the region are very low because of the variability of monsoon rainfall, which is erratic, unpredictable and highly fluctuating between years. The change in climate during the last decade has resulted in frequent droughts and unprecedented storms during crop maturity, resulting in losses to farmers, forcing them to change their land uses. Soil erosion causing sizeable loss of soil and nutrients, is primarily responsible for low productivity and poor economic status of the farmers in the area. The region receives an average annual rainfall of about 1100 mm, but 80% falls during summer monsoon months (July to September) with highly intensity. This results in serious problem of soil erosion in the region, through rainfall excess in summer monsoon months, and soil moisture deficit in the winter months. The average potential evapotranspiration (PET) exceeds rainfall during the months of March to June, subjecting crops to moisture stress. Keeping in view the precipitation variability and change in climate in recent times, the farmers of the region have developed various indigenous agricultural techniques apart from change in land use, to meet the challenges of moisture stress. They are rejuvenating the age-old but still existing village ponds for obtaining water for domestic uses, and irrigation of high value crops (e.g. in horticulture and agroforestry). There is need for scientific assessments of storage capacity and related hydro-geomorphic characteristics of village ponds. Adoption of some of the practices such as off-season tillage, mulching, dead furrows, graded border strips, raised bed sowing of maize, and across the slope cultivation, are being promoted to adapt to the climate change and water scarcity.

Keywords: climate change, foothills of Himalayas, land use, village ponds, production techniques.

2.2.3. Climate change and water: challenges and technological solutions in dry areas

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The Central and West Asia and North Africa region (CWANA) constitutes a large proportion of the world's dry areas. Most of the CWANA countries are already very dry, with low (100-500 mm) and erratic annual rainfall, and high temperatures during parts of spring, which is the critical period of crop growth, and during much of the summer cropping season. Climate models predict even lower rainfall and more frequent and intense droughts. This climate change will affect not only crop productivity but also river flows and ground water recharge. Water shortages will become more acute, creating conflicts between different groups of users such as farmers, urban households, tourism and industry. To anticipate the effects of climate change on crop production and water resources, and to develop adaptation options, ICARDA has focused its research on aspects related to water and its efficient use. ICARDA's research in rainfed areas has shown that water productivity under supplemental irrigation is as high as 2.5 kg of wheat grain per cubic meter of water, compared to 0.5 kg under rainfed conditions and 1 kg under full irrigation. In the Tadla region of Morocco, the combination of early planting with a little supplemental irrigation in spring doubled yield and water productivity, and helped the wheat crop escape terminal drought and heat stress. In drier areas, water harvesting techniques can reduce rainwater loss by runoff and evaporation from 90% to 40%. In the badia (steppe) rangelands of Jordan, it was demonstrated that micro-catchment techniques improve vegetation cover, reduce erosion and increase water productivity. Since improved technologies for water management help conserve and protect natural resources, and improve food security for the poor despite the effects of climate change, ICARDA will continue to address issues of water management, and new research areas specific to climate change have been identified and promoted. A modeling activity has also been conducted to simulate wheat production under different scenarios of CO2 levels, temperature increases and rainfall regimes, and to evaluate the role of supplemental irrigation as one potential adaptation measure to cope with climate change. In addition, studies on genotypic variation of crops under a combination of high temperature and available rainfall under field conditions will provide new insights.

Keywords: climate change, CWANA, crop modeling, drought, supplemental irrigation, water harvesting.

2.2.4. Desertification and its impacts on agriculture, biodiversity and water resources in drylands of Nigeria

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Desertification is land degradation in arid, semi-arid and dry sub-humid areas. Some 45 million Nigerians live in these areas, which have the highest incident of poverty, and lowest development indicators. Desertification is moving inland at 0.6 km per year, resulting from various factors including climatic variations and human activities. It is affecting the livelihoods of millions of people in the arid and semi-arid zone of northern Nigeria. The visible sign of this problem is the gradual decrease of vegetation cover and accentuating water shortage. Desertification is a major threat to the ecosystem that is being worsened by droughts, water crisis, deforestation, etc. The current food crisis in Africa needs to be examined in line with the environmental challenge of desertification and land degradation in the dylands. The FAO forecasts that there will be a need for a 50% growth in food production by 2030 to meet the food needs of the growing population, but this is threatened by desertification. This paper examines the causes of desertification in Nigeria's drylands and proposes solutions to the impacts, as well as identifies strategies for food security.

Keywords: arid and semi-arid areas, desertification, northern Nigeria, vegetation cover, water shortage.

2.2.5. Predicting unmet irrigation water demands due to climate change in the lower Jordan River Basin

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This study investigates the vulnerability of irrigated agriculture due to climate change in the Lower Jordan River Basin. The approach chosen is to assess unmet irrigation demands through modeling future water resource availability. The Water Evaluation and Planning System (WEAP) is used to simulate current water balances and evaluate future trends. A set of scenarios is composed of projections on population growth and domestic/agricultural water use efficiencies, and a second set of scenarios is based on climate change projections derived from General Circulation Models (GCMs).

Results from the model show a general tendency of higher unmet irrigation demands in the highlands where groundwater is the source of supply. Projected water shortages in irrigated agriculture of the highlands are most pronounced for the Amman-Zarka basin, indicating the high competition for water with growing urban demands. The vulnerability of irrigated agriculture in the Jordan Valley is comparatively lower, merely pronounced for the North and North East Ghor that are supplied with surface water. In contrast, irrigated areas in the southern Jordan Valley are benefiting from increasing urban demands that result in increasing return flows of treated wastewater to these irrigation schemes. A closer look at the King Abdullah Canal (KAC) reveals a buffering capacity in its northern segment that allows it to mitigate unmet water demands for the North and North East Ghor, if water reserved to supply the southern parts is shifted to the north.

Keywords: climate change, irrigated agriculture, Lower Jordan River Basin, WEAP.

2.2.6. Strategic planning for water resources management and agricultural development for drought mitigation in Lebanon

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Dominated by the westerly and the low pressure fronts coming from north and central Europe, Lebanon has relatively favorable conditions regarding annual precipitation, as compared to other countries in the Near East region. However, a significant decrease in rainfall patterns was observed during the past few decades. Moreover, increases have been found in the annual averages of daily maximum and minimum temperatures, and the number of summer nights. It is predicted that by year 2050, Lebanon will experience a reduction in average rainfall during the wet season, and available surface and groundwater resources of the country are insufficient to support the required agricultural production. Furthermore, reduced vegetation cover due to deforestation, overgrazing and poor surface management of cultivated lands, have led to reduced infiltration rate, increased runoff and soil erosion, and a decline in ground water recharge. Due to this alarming situation, various efforts have been recently made in Lebanon to assess and predict the impacts of climate change on water resources and agriculture. However, providing a national strategy which can be applicable for the whole country is very difficult, but long-term policies at both national and regional levels, assessing the vulnerability of water and agriculture in each area, nevertheless, needs to be localized.

Keywords: climate change, water resources, agricultural development, surface water, ground water.

2.2.7. Stream flow response to climate variability in several sub-watersheds of the Sebou river basin, Morocco

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Morocco, like many other Mediterranean countries, is facing water resource scarcity due to its arid to semi-arid conditions, aggravated by recent climatic changes. Recurrent drought events have occurred in the last five decades, impacting significantly on both surface and ground water resources. Stream flows, which are the main water source of the major reservoirs used for irrigation, drinking water, and hydro-power, are particularly affected by these changes. In this paper, long term trends of stream flow in relation to climatic data were studied in four sub-basins of the Sebou watershed in northern Morocco. A hydrologic simulation was performed on one of the sub-watershed using two hydrologic models, IHACRES and HEC-HMS. Over the past five decades, stream flow and precipitation data showed a cyclic trend as well as a general decline, with variable amplitude from one sub-basin to another. Recorded stream flows were significantly correlated with the corresponding precipitation values. An average rainfall decline over the past 50 years varied from 285 mm to 150 mm, corresponding to about a 25% decrease. Stream flow modeling with both models gave very reasonable simulations that were comparable over the series studied. Differences between years with contrasting climatic conditions were well illustrated and showed large disparities in terms of total annual discharges, ranging from 0.93 billion m3/yr to 5.3 billion m3/yr, for dry and wet year conditions, respectively. The models used can serve as tools for predictions of stream flows in response to climatic variability for sound water resource management.

Keywords: climate change, stream flow, modeling, IHACRES, HEC-HMS, Morocco.

2.2.8. Impact of climate change on agriculture, biodiversity and natural resources management in semi-arid regions of Nyeri and Likipia districts, Kenya

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A study was conducted in April 2009 to assess changes in climate, farming, biodiversity and the environment in semi-arid regions of Nyeri and Laikipia districts of Kenya. The two districts were respectively composed of 42% and 69% semi-arid lands, and of low agricultural potential. The majority (91%) of the inhabitants were immigrants who settled there after 1990 due to increased population in the high potential areas of Central Kenya. Of the farmers interviewed, 100% were aware of climate change and biodiversity losses, and 61% said that climate has deteriorated within the last 10 years. The main indicators are erratic and low rainfall, frequent droughts, low crop yields, and high day and low night time temperatures. Decreased water levels in rivers have heightened conflicts between upstream and downstream users. Changes in biodiversity have been the disappearance of wild animals and insects such as safari ants, and an upsurge of pests (centipedes, millipedes and birds). Plants lost are mainly those with important cultural value, like medicinal, fuel wood and fodder species and those with other traditional uses. Agriculture has been declining, the major causes being low rainfalls (60% of respondents), lack of availability of pastures (74%) and increased pests and diseases (11%). This study revealed an urgent need for scientists, government and non-government agencies and other stakeholders to support efforts by farmers in the mitigation of climate change through technological, policy and financial interventions, with an aim of improving livelihoods and food security of people living in such vulnerable dryland regions.

Keywords: climate change indicators, farmers' perceptions, climate change, semi-arid regions Kenya.

2.2.9. Climatic change and wheat rust epidemics: implications to food security in dry areas

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Biotic and abiotic stresses are the major limiting factors affecting sustainable wheat production worldwide. Among the biotic constraints, wheat rusts are the most devastating diseases of wheat. Favorable environmental conditions, overlapping crop calendar, inadequate level of resistance, and similar genetic background of mega-cultivars are the major driving forces of regional epidemics of wheat rusts. The consequence of global warming as defined by increases of atmospheric CO2 concentration, temperature, and frequency of extreme weather conditions has direct and/or indirect effect on population dynamics of wheat rust pathogens. These could have positive or negative effects on distribution of wheat rusts, frequency of physiological races, and adaptation of rust pathotypes to the regions not hit by epidemics of rust pathogens before. Genetic make-up, phenology and distribution of wheat cultivars could also be rapidly changing due to asynchronous responses to climatic changes. The emergence of wheat yellow rust in non-traditional areas, rapid detection and changes in frequency of new races, early yellow rust infection of wheat, susceptibility of current resistant cultivars to new rust populations, occurrence of wheat stem rust in cold areas, shifts in the predicted west-east migration pathways of rust spores, and finally the wide spread epidemics of yellow rust in warmer areas which is potentially an indication of adaptation to high temperatures, are considered primary consequences of climatic changes. In this paper, the current situation of wheat rust diseases in the dry areas associated with climatic changes and its implications for food security are discussed.

Keywords: climate change, epidemics of wheat rust, pathogen migration pathways, rust pathotypes.

2.2.10. Impact of climate change on diseases of food legumes in the dry areas

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Chickpea, faba bean, and lentil are the major food legume crops that provide dietary plant protein to millions of people, cash incomes to marginal farmers, and sustainability to the cereal-based cropping system in the dry areas of the world. The productivity, quality and expansion of food legumes are affected by several foliar and soil borne diseases. These diseases have global and regional importance depending on the environmental conditions that support their distribution and epidemic development. However, the extent of yield losses depends on the interactions of biophysical factor, mainly temperature, moisture, the pathogen and the host. Climate change, mainly rising temperatures and changes in moisture, is predicted to cause changes in the disease spectrum, particularly their distribution and epidemic development, and the appearance of new pathotypes affecting the crops. For example, Stemphylium blight in lentil was a minor disease but the introduction of lentil in rice-fallows of South Asia has aggravated this problem in the region. Similarly, unusual late rains can cause heavy pod infection by chickpea Ascochyta blight, leading to heavy yield losses and poor grain quality. The 1997-98 late rain caused by an El Niño event resulted in complete crop failure of late planted lentil due to rust in Ethiopia. Different temperature regimes were found to affect virulence-resistance in Ascochyta-chickpea and Ascochyta-lentil pathosystems. Additionally, temperature fluctuations can also influence the sexual reproduction of Ascochyta species. Increased soil moisture stress and extreme temperatures can affect host resistance. In addition to the existing key disease problems, new or minor pathogens are likely to become important under climate change. For example, increased dry conditions can favor dry root rot and powdery mildew in food legumes in some countries. Interactions among soil borne pathogens are being observed in many farmers' fields, notably the interaction of fungal pathogens with nematodes, or with soil inhabiting insect pests. Under climate change, research in food legume disease management strategies should focus on refinement of existing disease management recommendations, and engagement in anticipatory research to tackle emerging pathogens through multidisciplinary team approaches. In this paper we discuss the potential impact of climate change on

important diseases of food legumes, and mitigation and adaptation strategies to minimize their detrimental effects

Keywords: climate change, food legumes, disease management, foliar diseases, soil borne diseases.

2.2.11. Implications of climate change on insects: the case of cereal and legume crops in North Africa, West and Central Asia

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The expected decrease in precipitation by about 25% and the increase in temperatures by 3-4ºC by 2099 in North Africa, West and Central Asia (CWANA) would have great impacts on insect pests and their natural enemies. Warmer environments would favor rapid insect development giving rise to more insect generations per year and thus higher population sizes of the pests. This in turn, would cause more damage to crops and would also accelerate the development of new biotypes. Higher temperatures would favor the extension of the geographical distribution of the pests within the CWANA region and beyond, and these climate changes could create favorable environmental conditions for some secondary insects to become key pests. Surveys must be continuously conducted in the region to assess the importance of insect pests and their natural enemies and to monitor changes in their population structures as might be influenced by these climate changes. Warmer and drier climates would require the use of appropriate management options, such as the use of resistant varieties possessing stable genes under higher temperature regimes, new planting dates, new biopesticide formulations allowing a better efficacy and persistence, and adapted natural enemies to these new climatic conditions.

Keywords: climate change, insects, cereals, legumes.

2.2.12. Climate change impact on weeds

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The impact of climate change on single species and ecosystems are likely to be complex. However, in contrast to crops, weeds are troublesome invaders, ecological opportunists and resilient plants with far more genetic diversity. Weed populations include individuals with the ability to adapt and flourish in different types of habitats. Weeds benefit far more than crop plants from higher levels of CO2, and the implications of this for agriculture and public health are grave. Weeds are able to respond rapidly to disturbances giving them a competitive advantage over less aggressive species, particularly crops. Enhancing CO2 levels not only increases growth rates of many weeds, but may lead to changes in their chemical composition. When ragweed (Ambrosia sp.) was grown in an atmosphere with 600 ppm of CO2 (the level projected for the end of this century), they produced twice as much pollen as plants grown in an atmosphere with 370 ppm, and the pollen harvested from the CO2-enriched atmosphere proved far richer in the protein that causes allergic reactions. Interactions between climate change and crop management in any agro-ecosystem may turn some currently benign species into invasive species, thus leading to changes in weed composition. As climatic zones shift, weeds that are capable of rapid dispersal and establishment have the potential to invade new areas and increase their range. Developing techniques for managing the increasing burden of the upcoming weed situations will be essential. However, the effect of elevated levels of CO2 on increasing growth rates of certain weed species may turn them into beneficial species with better sources of energy and biofuels.

Keywords: climate change, crop-weed competition, elevated CO2 level effects, invasive species.

2.2.13. Is climate change driving indigenous livestock to extinction? A simulation study of Jordan's indigenous cattle

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Nearly all developing countries promote expansion of livestock products to meet the food demand of the increasing human population. Jordan, as a developing country, has not yet attained self-sufficiency in livestock products. Therefore, it is aiming to increase the productivity and the number of animals to meet the domestic needs of Jordan for animal products. However, the number of livestock is showing a continuous annual reduction. This is attributed to the reduction in water supply and consequently less availability of animal feed because of climate change, e.g. less rainfall and high temperature. The objectives of this study were to simulate the extinction probabilities (PE) of livestock under effect of different drought levels using the Vortex® modelling program, using as an example, the indigenous cattle of Jordan. Using the census data, effective population size (Ne) was calculated and found to be almost half (Ne = 40) of what is recommended (Ne = 82) by FAO to escape them becoming endangered. Furthermore, the EP, growth rate, heterozygosity and inbreeding rate were simulated for a past and future time horizon. The model concludes that the indigenous cattle are currently expected to decline rapidly toward extinction within the coming years, considering the same assumed climate conditions of less rain, more drought and increased feed scarcity.

Keywords: climate change, water scarcity, extinction probabilities, indigenous livestock, feed resource.

2.3.1. Food security in the occupied Palestinian territory

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Palestinians' food insecurity is rooted in the limitations to access food, as a sub-set of poverty, and erosion of their livelihoods. Agricultural production should secure food for around 3.76 million Palestinians living in the occupied Palestinian territory (oPt). However, the total agricultural land area covers 30.5% (1834.8 km2) of the occupied Palestinian territory and 54.4% of the total suitable land for cultivation. Dryland farming covers 85.3% of the total cultivated area. Due to the limitations of soil fertility and drought, the contribution of dryland agriculture is limited and amounts to 8.6% of the total plant production in the occupied Palestinian territory, especially because the average annual rainfall has decreased in the last three years by 15%. Unemployment and poverty rates are high, reaching 25.4% and 38.5% in the West Bank and the Gaza Strip, respectively, in 2009. Food prices have also increased by 22% in 2008. Accordingly, 35% of Palestinian households (1.6 million Palestinians) are food insecure in 2009. To understand the causes behind Palestinian food insecurity, the World Food Program (WFP) and the Applied Research Institute Jerusalem (ARIJ) jointly produced a Food Security Atlas, where key issues were addressed, including economic issues, access and political situation, livelihood crisis, production capacity, education and malnutrition, environmental and climatic impacts, food prices, and quality, etc. The details are presented in this paper.

Keywords: dryland agriculture, food security, occupied Palestinian territory, World Food Program.

2.3.2. Status of current food security in Palestine and future scenarios under changing climates

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The Palestinian population in the West Bank and Gaza Strip is about 2.4 million and 1.5 million, respectively. Out of a total surface area of 642,000 ha, 27% is devoted to the agricultural sector, which is the major economic activity in this area. Indeed, more than 50% of the Palestinian people benefit from agricultural returns. Recent assessments have shown that 38% of the population is food insecure. In addition, 11% and 16% of the population in the West Bank and Gaza Strip, respectively, is vulnerable to food insecurity. This situation is related mainly to the limitations imposed by Israel on Palestinians from accessing their resources, including land, irrigation water, jobs, etc., to get enough food. Continuous drought in the last decade, including the decline in average rainfall and increases in temperature, have also affected Palestinian agricultural livelihoods and increased the food insecurity. To overcome the food insecurity problem, Palestinians have to access their land and water resources. In addition, a strategy for sustainable agriculture depending on less water consumption, such as using zero (no) tillage culture, improving water harvesting techniques, using efficient irrigation systems, and developing new drought and salinity resistant cultivars, could be promising.

Keywords: food security, West Bank, Gaza Strip, sustainable agriculture.

2.3.3. Adaptation to climate change in dryland agriculture: issues and implications

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According to the Intergovernmental Panel on Climate Change (IPCC) report in 2007, the impacts of climate change and their associated costs will fall disproportionately on developing countries, threatening to undermine the goals of reducing poverty and safeguarding food security. Food availability and quality is determined by the complex interactions between agro-climatic conditions and technological drivers such as nutrient application, irrigation, and seed selection. Therefore, the consequences of climate change in terms of its impact on the amount and distribution of farmers' returns will affect farmers' decisions to adopt these technological drivers in their quest to adapt to climate change. Although average crop yields and returns may change disproportionately across agro-ecological systems, uncertainty and variability of the returns is expected to increase as a consequence of the increase in climate variability and weather extremes. It is of critical concern to farmers, agricultural extension agents, government planners, researchers, and the donor community to clarify the extent to which climate change will impact agro-ecological production systems. This paper uses decision theory to derive analytically decision rules to apply inorganic fertilizers, irrigation water, and choice of crop varieties under climate change, and apply these rules to cases of cotton and wheat in Syria under alternative scenarios of climate change. The paper draws from the research and policy implications of the analytical results.

Keywords: climate change, cotton, decision theory, policy implications, poverty reduction, technological drivers, wheat.

2.3.4. Climate variability and rural livelihood: mitigating the impact of agricultural salinity in a changing climate in Sri Lanka

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Since climate change has particularly severe impacts on rural agrarian communities, it is important to strengthen their livelihoods and re-establish the conceptual links between poverty (defined as the lack of stable purchasing power to maintain decent living standards), livelihood, and the environment. Perhaps the most important prerequisite for creating sustainable livelihoods and for achieving sustainable development is good and accessible governance. Thus, the links between the community and local, state, and national governments are of utmost importance. The aim of this study was to survey climate change impacts and local perception of climatic hazards, including assessment and analysis of capacities and coping strategies; to conduct an inventory of the available technological advances to combat agricultural salinity; to formulate adaptation strategies to reduce the vulnerability to agricultural salinity through a participatory mechanism; to develop appropriate extension tools; and to establish demonstration sites in collaboration with relevant technical agencies with selected adaptations. In this study, traditional rice (Oryza sativa) varieties like Pachaperumal, Kaluheenati, Dahanala, and Rathdal, and hybrid varieties, were introduced through Variety Adaptability Trials (VATs), with organic and in-organic agronomic practices, in selected farmer fields in high salinity areas. The salinity build up of paddy fields in Angiththamkulam Yaya and Kattakaduwa is high due to the accumulation of salts from irrigation water and salt, forming parent materials present in the soil profile. Therefore, the introduction of mitigation options is important to reduce effects of salinity. Improved drainage facilities to remove excess salts reduce the salt accumulation in the soil. Application of organic manure such as compost, straw, and burnt paddy husk improves soil fertility in salt affected paddy fields. The most susceptible stage of rice to saline conditions is the seedling stage, and so, transplanting is a more suitable establishment method than broadcasting. As a result of the above mitigation options, the electrical conductivity of the soil was reduced and remained at a low level during the growing season, and grain yields of 3 t/ha could be obtained from the salt susceptible rice variety Bg 352. Introduction of salt tolerant rice varieties was the best and low cost option to increase the productivity of salt affected paddy fields. In addition, newly developed salt tolerant lines at RRDI (11-139, 5-110 and 4–91) performed well, and yield levels of 5-7 t/ha could be obtained. Traditional varieties like Rathdal and Pachperumal were susceptible to saline conditions.

Keywords: climate change, rural livelihoods, salinity, sustainable livelihoods, salt tolerant rice varieties.

2.3.5. Gender, food insecurity and climate change amongst pastoral communities: case studies in Mandera and Turkana in northern Kenya

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Kenyan pastoralists earn the livelihoods in the arid and semi-arid lands. The roles, relations, responsibilities, opportunities and constraints of pastoralists pose different challenges to women and men, because of the unequal access and control of resources. With few studies undertaken on the impact of climate change and its consequences, this study focuses on using quantitative and qualitative methods and a multidimensional approach to assess vulnerability. Using data on pastoralist's attitudes and perceptions related to climate change and variability on food security, it was found that women's workloads and the pastoralists over-

reliance on food relief increased because of climate variability and change.

Keywords: climate change, food relief, food security, gender difference in vulnerability.

2.3.6. Oil exploration, climate change and food security in the Niger delta, Nigeria

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Crude oil exploration and subsequent take-off of oil related industries since the middle of the last century in Nigeria has been largely responsible for the metamorphosis of the country, from a producer of a few primary commodities to a country depending exclusively on crude oil exports for its foreign exchange earnings. No doubt, the country has greatly benefited from the oil production enterprise, some of the activities of various oil companies working in the Niger delta of Nigeria (especially gas flaring and oil spillage that accompany oil exploration/ production) have contributed immensely to change in climatic conditions of the area, and adversely affected the flora and fauna of the ecosystem, and therefore brought untold hardship on lives, means of livelihood, and food security of people inhabiting this area. This study examines causes and effects of improper and unethical disposal of associated gases through flaring, and the perennial problem of oil spillage in the concerned localities, which are damaging the environment and adversely affecting agricultural production and food security through changes in temperature, water availability, soil conditions, frequency of extreme weather events, and acid rain. The study further provides background information on the interrelationship between climate change and food security in the Niger delta of Nigeria, and ways to deal with the new threat. It also suggests the way forward for the agriculture sector, as well as describing how all stakeholders can contribute to reduce the climate challenge, and ensure guaranteed, stable and unhampered food production in the area.

Keywords: climate change, food security, Niger delta, Nigeria, oil spillage.

2.3.7. Climate change induced migration among farmers in dryland zones of Nigeria

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This paper presents the trends and pattern, as well as determinants, of climate change induced migration among farmers in dryland areas of Nigeria. This is based on the fact that agriculture, which plays a leading role in the non-oil sector of Nigeria and is principally practiced by small-scale farmers at subsistent level, is rainfed. This exposes the farmers to the vagaries of weather and variability over the years has led to reduced accuracy in predicting patterns of rainfall and other climatic features. The effect of climate change has made the fluctuations in climatic conditions more severe, such as rises in temperature and severe drought events, among other effects. In response to the foregoing, farmers are migrating to areas where they can have more assured livelihoods. Over the last few years, the use of wetlands, floodplains and inland valleys for agriculture has increased, by both pastoral and agro-pastoral communities, because of their high potential for a diversity of livelihood activities and their importance for poverty reduction and wealth creation to local communities, with less disruption by climatic features. A cluster sampling technique was used to select 100 farmers from each of the dryland zones that are cultivating wetlands, and a structured questionnaire was used to elicit information on trends and patterns as well as determinants of their migration to the wetlands. Data collected were described using frequency and

percentages, and a multiple regression analysis was used to identify significant variables that are determinants of migration. The results of the analysis show that significant variables include location/distance of wetland, household size, crop preferences, farming system, drought proneness, changing ecosystems, and farmers' age.

Keywords: agro-pastoral communities, climate change, drylands, migration, subsistence farming.

2.4.1. Plant genetic resource management and discovering genes for designing crops resilient to changing climates

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Climate change is expected to result in increased frequency of drought, heat stress, submergence, increased soil salinity, etc. Much of the existing literature assumes that farmers will automatically adapt to climate change and thereby lessen many of its potential negative impacts, taking for granted the monumental past efforts at the collection, conservation and utilization of plant genetic resources on which much of farmer adaptation has historically depended. Given potentially large climatic changes, it is dangerous to assume that adaptation of cultivars will happen automatically. Extensive crop breeding that relies on access to genetic resources will almost certainly be required for crop adaptation under conditions of global climate change. Key to successful crop improvement is a continued supply of genetic diversity, including new or improved variability for target traits such as early flowering as an escape mechanism to drought, variation in root traits, water use efficiency, amount of water transpired, transpiration efficiency, osmotic adjustment, stem water soluble carbohydrates, stay green, and leaf abscisic acid reported in many crops. The core/minicore collections developed for many genebank collections may provide new sources of variation for beneficial adaptive traits to climate change. Substantial knowledge and insight is therefore needed to gauge what type of diversity now exists in the genebanks, and what will be needed in the future. Greater investments need to be made in phenotyping and genotyping the native genetic variation contained in seed banks and collecting the remaining diversity particularly that associated with traits of value to crop adaptation to climate change. Plant breeders and other users of genebank collections should play a key role in shaping these efforts to ensure that the end result is useful.

Keywords: biodiversity, core collection, drought, genebank, traits for adaptation to climate change

2.4.2. Potential and relevance of dryland agrobiodiversity conservation to adapt to adverse effects of climate change

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The region of Central, West Asia and North Africa (CWANA), which encompasses major centers of diversity of many crops of global importance, is expected to experience the adverse effects of climate change more than many other dry areas. It is imperative therefore, that plant breeding efforts are focused on the production of high yielding varieties that are tolerant to higher temperatures and more frequent drought episodes. In this context, landraces and wild relatives of crop plants that are still found within the prevailing traditional farming systems in the drylands and mountainous regions are potential sources of useful genes for plant breeding, focused on the adverse effects of climate change. Unfortunately, the remaining hotspots of dryland biodiversity cannot be sustained due to the combined effects of over-

exploitation of agricultural land, destruction of natural habitats, and modernization of traditional farming systems, which includes replacement of landraces with modern varieties. The region is thus in danger of losing valuable genetic material that has the potential to contribute to climate change solutions. Thus one facet of food security within the context of climate change will be to take measures to secure the region's genetic resources. The International Center for Agricultural Research in the Dry Areas (ICARDA) is playing a major role in promoting the conservation of genetic resources of cereals, and food and forage legumes, as well as various pasture and range species. ICARDA holds more than 134,000 accessions in its genebank, 68% of which were collected in the CWANA region. Further, its coordination and joint implementation of the GEF-UNDP funded project entitled 'Conservation and sustainable use of dryland agrobiodiversity in Jordan, Lebanon, Palestine and Syria' has allowed the development of a holistic approach for promoting community-driven in situ/on-farm conservation of dryland agrobiodiversity. This project assessed the status and major threats to landraces and wild relatives of cereals, food legumes, forage legumes and several fruit trees originating from the West Asia centre of diversity, and developed recommendations for their conservation. Remaining areas rich in biodiversity still need to be identified, and appropriate in situ conservation management plans require implementation. In summary, rehabilitation of degraded ecosystems as well as appropriate ex situ and in situ conservation measures need to be promoted at national, regional and international levels to ensure the continuous supply of adapted genetic resources to supply crop improvement programs. While a wealth of genetic resources have been collected from the region and conserved in genebanks, a thorough gap analysis is needed to identify areas in which native germplasm is still evolving under harsh conditions, so that existing ex situ holdings can be enriched by targeted seed collection missions. To facilitate the efficient and effective exploitation of large ex situ collections for climate change breeding, a rational method is required to select appropriate material from genebanks to screen for desirable traits. ICARDA, in partnership with ARIs, is developing a set selection methodology, the Focused Identification of Germplasm Strategy (FIGS), that uses detailed agro-climatic data and statistical models to develop tailor-made trait-specific subsets of germplasm for breeding programs. Once appropriate donor germplasm has been identified, intensive pre-breeding activities are needed to introgress genes from landraces and wild relatives into improved genetic backgrounds. This paper presents ICARDA's strategy to promote ex situ and in situ conservation of dryland agrobiodiversity and its subsequent use in plant breeding efforts for dryland areas that will be affected by climate change.

Keywords: adaptation, climate change, conservation, dryland agrobiodiversity.

2.4.3. Reviving beneficial genetic diversity in dryland agriculture: a key issue to mitigate negative impacts of climate change

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The unpredictable nature of climate change challenges the most of the established agricultural practices. The concept of food security and yield stability must be addressed with regards to all possible agronomic solutions to future climatic instability. Evolutionary and participatory plant breeding methods are effective approaches to the agronomic problems associated with climate change. One of the main objectives of conventional breeding programs for self-pollinating cereal crops is to develop genetically uniform varieties. This

genetic uniformity is considered as a negative factor in tackling the adverse impacts of environmental and climatic changes. Breeding for sustainability is a process of fitting varieties to an environment, instead of changing the growing environment by using fertilizer, water, pesticides, etc., to fit varieties. In participatory and evolutionary plant breeding methods, farmer selection, working with natural selection on a genetically diverse population, will allow for the maximum adaptation to environments with specific stresses, and also maximum resilience against climate change. Recognizing the negative impact of global warming and climatic change on cereal production in rainfed conditions in Iran, and to counter it with the use of beneficial genetic diversity, we have started a program on participatory and evolutionary cereal plant breeding in two provinces of Iran. The paper presents the results from this work.

Keywords: cereals, climate change, evolutionary and participatory plant breeding, rainfed agriculture.

2.4.4. Conservation and sustainable use of plant genetic resources as a strategy to support agriculture in achieving food security, and promote adaptation to climate change in the Near East and North Africa

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The Near East and North Africa (NENA) region is widely recognized for the rich diversity of plant genetic resources (PGRs) for food and agriculture. In fact, most agricultural plant species cultivated in the temperate zone originated from, and were first domesticated, in this region. Indigenous farmers' varieties of the crops originating here are still used in traditional farming systems. The region also has wild relatives for a number of crop plants that can be found in their natural habitats. Such diversity has been under threat due to increased demographic pressure combined with degradation of arable land, over-exploitation and destruction of natural habitats, as well as expansion in the use of improved varieties and introduction of alternative crops with a narrow genetic base.
Only a limited part of the PGR diversity has been collected, characterized, evaluated and conserved in agricultural genebanks established in the region.
The paper demonstrates how contemporary genebank management practices and improved documentation systems of PGRs contribute to the effective conservation and sustainable use of agrobiodiversity. A Regional PGR Network has recently been established under the auspices of the Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA), as a platform for collaboration on PGRs. The Network can play a significant role in setting priorities and facilitating collaborative action on PGR. The paper highlights the major objectives and approaches of the network in promoting conservation and sustainable use of PGR as a strategy that supports agriculture in the region to meet the broader challenges of food and nutritional security and climate change.

Keywords: AARINENA, adaptation, climate change, conservation, dryland agrobiodiversity, NENA region, plant genetic resources (PGR), wild relatives of crop plants.

2.4.5. Plant breeding and climate change

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Climate change is now unequivocal, particularly in terms of increasing temperature, increasing CO2 concentration, widespread melting of snow and ice, and rising global average sea level, while the increase in the frequency of drought is very likely but not as certain. Yet, climate changes are not new and some of them have had dramatic impacts such as the appearance of leaves about 400 million years ago as a response to a drastic decrease of CO2 concentration, the birth of agriculture due to the end of the last ice age about 11,000 years ago, and the collapse of civilizations due to the late Holocene droughts between 5000 and 1000 years ago. The climate change which is occurring now will have – and is already having – an adverse effect on food production and food quality especially with the poorest farmers and the poorest countries most at risk. The adverse effect is either a consequence of the expected or likely increased frequency of some abiotic stresses such as heat and drought, and of the increased frequency of biotic stresses (pests and diseases), and climate change is also expected to cause losses of biodiversity, mainly in the more marginal environments. Plant breeding has always address both abiotic and biotic stresses, and strategies of adaptation to climate changes may include a more accurate matching of phenology to moisture availability using photoperiod-temperature responses, increase access to a suite of varieties with different duration to escape or avoid predictable occurrences of stress at critical periods in crop life cycles, improved water use efficiency, and re-emphasize population breeding, in the form of evolutionary participatory plant breeding to provide a buffer against increased unpredictability. ICARDA has recently started evolutionary participatory programs in barley and durum wheat. These measures will go hand in hand with breeding for resistance to biotic stresses, and with an efficient system of variety delivery to farmers.

Keywords: abiotic and biotic stresses, barley, climate change, durum wheat, evolutionary participatory plant breeding.

2.4.6. Genotype x environment interaction for durum wheat yield in different climate and water regime conditions in Iran

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Wheat genotypes grown in Mediterranean area are exposed to variable rainfed environments. Climate change predictions indicate that the frequency of dry years will likely increase in the future. To cope with the global climate change, which will be resulting in change in the performance of wheat genotypes, study of genotype-environment (G × E) interaction is necessary to develop varieties that are adapted to variable environments. The G x E interaction plays a significant role in the relative expression of yield potential of different cultivars in different environments. This study examined 20 durum wheat genotypes over 19 diversified environments representing different ecosystems (west, north west and north east Iran), different water regimes in each location (rain-fed and supplemental irrigation) and different climates (warm, moderately cold and cold winters) during three cropping seasons (2005–2007). Pattern analysis, cluster and ordination techniques, were

applied to the grain yield data. Results indicated that the main effects due to environment (E), genotype (G) and G×E interaction were highly significant, and 0.85 of the total sum of squares (SS) was accounted for by E. Of the remaining SS, the contribution of G×E interaction was almost 12 times that of G alone. The knowledge of environmental and genotype classification helped to reveal several patterns of G×E interaction. This was verified by ordination analysis of the G×E interaction matrix. Grouping of environments, based on genotype performance, resulted in the separation of different types of environments. Pattern analysis confirmed the cold and warm mega-environments, and allowed the discrimination and characterization of adaptation of genotypes. However, several patterns of G×E interaction in Iran's regional durum yield trials were further discerned within these mega-environments. The warm environments tended to be closer to one another, suggesting that they discriminate among durum genotypes similarly, whereas cold environments tended to diverge more. The dwarf and early maturing breeding lines from ICARDA with low to medium yields and high contribution to G×E interaction were highly adapted to warm environments, whereas the tall and later maturing genotypes with low to high yields were highly adapted to the cold environments of Iran.

Keywords: climate changes, durum wheat, genotype x environment interaction, pattern analysis, yield stability.

2.4.7. Thermo-tolerance studies for barley (Hordeum vulgare L.) varieties from arid and temperate regions

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Water deficits are clearly a major determinant of global crop yields and in severe cases can lead to plant death. There is a tacit assumption that this arises through low water concentrations in plants, and the key to developing drought tolerant crops, therefore, is to identify and manipulate water acquisition and conservation traits in plants. Plants growing in arid regions, however, are also usually exposed to high air temperatures. What traits should plant biologists focus on; water conservation or thermotolerance? To address this question an uncharacterized barley line from hot arid regions of Pakistan 'Local' was compared with an elite European line 'Optic' for its thermo tolerance abilities. Assimilation rates (A) and Vrubisco were suppressed in both lines immediately after heat shock but after 5 days the tolerant line Local showed a recovery of 23% for both parameters ($p < 0.05$), while Optic did not recover at all. Moreover chlorophyll fluorescence and photosynthetic efficiency studies in both lines suggest that the progressive decline of assimilation rates above 36°C in both lines can not be attributed to stomatal closure or impairment of light harvesting complex and must, therefore, be attributed to thermal inactivation of other components of the photosynthatic process.

Keywords: arid regions, barley, drought tolerance, photosynthesis, thermotolerance.

2.4.8. Potential of improving and stabilizing wheat yields in the context of climate change

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In the West Asia and North Africa (WANA) region, increasing water shortages due to more frequent droughts and the growing demand for water for industrial, tourism and domestic uses, will result in less water for crop production in the future. The crops that will suffer most from this are cereals, because during droughts, they benefit less from irrigation water, and because they are mainly grown in arid zones where opportunities for irrigation are very low. Approaches that can help reduce future water shortages and increase food production include the capture of more rainwater and better use of scarce irrigation water through the adoption of new improved technologies. Research conducted in the region has shown that supplemental irrigation (SI) using limited amounts of water at critical stages, zero tillage (ZT) and improved varieties, significantly increase and stabilize yields of wheat under rainfed conditions in WANA countries. Combining these technologies would improve and stabilize land productivity and help plants adapt to climate change. The objective of this study was to evaluate the additive effects of ZT, SI and genotype (G) on land and water productivity, during a trial conducted at ICARDA's research station in Tel Hadya, Aleppo, Syria in 2008/09. The treatments tested were 'zero tillage vs. conventional tillage (CT)', 'supplemental irrigation at boot stage (35 mm) and milk stage (35 mm) vs. the rainfed regime (RD)', and five genotypes of bread wheat (Cham 6, Cham 8, Shuha, Cham 10, Raaid-3). Results showed that zero tillage improved leaf area index, specific leaf area index, evapotranspiration (ET), above ground biomass production, and biomass water productivity at the beginning of stem elongation; and in general, all varieties responded positively to zero tillage for these measured parameters. At maturity, zero tillage under rainfed conditions, and supplemental irrigation under conventional tillage, increased ET by 30 mm and 61 mm, respectively, as compared to conventional tillage under the rainfed regime. The combination of zero tillage and supplemental irrigation, however, increased water use by 110 mm. Consequently, grain yield increased, on average, from 4515 kg/ha under conventional tillage in the rainfed regime, to 5929 kg/ha where zero tillage and supplemental irrigation were combined. The yield difference between the treatments 'ZT+RD' (5063 kg/ha) and 'SI+CT' (5244 kg/ha) were not significant. All the genotypes responded positively, but differently, to ZT and SI, with Cham 6, Cham 8 and Shuha the most responsive. Water productivity was not, however, affected by the tested treatments because both the yield and ET were increased by ZT and SI. The preliminary results showed that the combination of ZT and SI can improve the capture of rainwater and the use of supplemental irrigation, and hence increase land productivity under drought conditions.

Keywords: arid zone, drought, evapotranspiration, rainfed conditions, supplemental irrigation, WANA region, water shortage, wheat genotypes, zero tillage

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2.4.9. Breeding food legumes for enhanced drought and heat tolerance to cope with climate change

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Frequent droughts and fluctuations in temperature are inevitable under changing climates. For sustainable food and nutritional security, cereal-based farming systems need to incorporate food legumes best suited to climate change. Chickpea, lentil, faba bean, and grasspea are important cool-season food legumes commonly grown under rainfed conditions in non-tropical dry areas worldwide. Drought and heat stress especially after the onset of flowering are of common occurrence in most of these environments, causing substantial yield losses. The International Centre for Agricultural Research in the Dry Areas (ICARDA), a centre of excellence for these crops, lays emphasis on improving the yield potential and stability of these crops by incorporating genes for drought and heat tolerance, productivity and resistance to key diseases to keep ICARDA and NARS breeding programs on front foot. ICARDA's main research stations is at Tel Hadya, Aleppo, Syria, with 350 mm mean annual rainfall, with two substations at Breda (250 mm rainfall), Syria, and Terbol in the Bequa valley in Lebanon (450 mm rainfall), provide the opportunity to evaluate germplasm and elite advanced progenies under different moisture gradients. To adapt to climate change, ICARDA is channelizing its resources to identify drought and

heat tolerant genotypes using different screening methodologies, dissecting these complex traits into its components, and identify genes/QTLs for each component to pyramid them in good agronomic background using both conventional and molecular approaches. The current methodologies in use to screen for heat and drought in chickpea, lentil and faba bean include delayed planting of germplasm/improved materials to coincide flowering time with high temperature shocks, late planting on receding soil moisture and under low rainfall sites for drought. These methodologies have helped to improve germplasm and are being supplemented with genomic resources to generate additional knowledge which may further help in understanding these stresses. In this paper, we discuss breeding strategies for adaptation of food legume crops to cope with stresses under the climate changes.

Keywords: adaptation, climate change, drought, food legumes heat, germplasm, mitigation,

2.4.10. Community-based breeding programs to exploit genetic potential of adapted local sheep breeds in Ethiopia

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Indigenous breeds are likely to cope better with climate change than exotic breeds, because they are already adapted to harsh conditions. Breeding programs will not be able to improve adaptation traits in exotic breeds fast enough to keep pace with climate change. The better alternative is to focus on improving production traits in indigenous breeds. Designing breeding programs for indigenous breeds owned mostly by small-scale farmers requires, among others, an understanding of the production system of the target area and the definition of breeding objectives in a truly participatory manner. The research project presented here is designing community-based sheep breeding strategies in four locations, representing different agro-ecologies that provide the habitat to four indigenous sheep breeds (Afar, Bonga, Horro and Menz). The production systems were described using surveys and workshops. Breeding objective traits of sheep owners were identified by employing different methodologies such as surveys, hypothetical choice experiments, and ranking of live animals in the farmers' own flocks and of groups of animals penned in a central location. The application of various methods allowed a validity cross-check of results and ensured that all traits are captured. The production systems were characterized as a pastoral system for Afar, a mixed crop-livestock system for Horro and Bonga, and sheep-barley system for Menz. The mating system was predominantly uncontrolled. Early disposal of breeding stock, diseases and feed shortage (mainly in Afar and Menz) were identified as the major problems. Six traits for ewes (body size, coat color, mothering ability, twinning, lambing interval, tail type) and five traits for rams (body size, coat color, tail type, libido and presence or absence of horn) were identified as breeding objective traits of the smallholders, and one additional trait (milk yield) for Afar. This information was used in the simulation of alternative breeding strategies for the different communities and then discussed

Keywords: breeding objectives, community based breeding, Ethiopia, indigenous sheep breed,

2.4.11. New feeding strategies for Awassi sheep in drought affected areas, and their effects on product quality

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The rangelands of Middle Eastern countries are already severely degraded due to overgrazing in combination with frequent droughts. As a consequence, livestock farmers face high and increasing feeding costs in particular during the milk production period. It is predicted that climate change will worsen this situation due to increasing temperature, less rainfall and an even higher frequency of droughts. This study aims at counterbalancing this trend by using cheaper unconventional ingredients in balanced diets. The use of cost optimized supplemental diets was tested with 42 Awassi ewes at the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria. The sheep were allowed to graze daily on marginal rangelands for six hours. Milk production and dairy products obtained with the conventional supplementary feed used by farmers was contrasted with production under 5 cost optimized nutrient balanced diets. In one of treatment groups (T5), the sheep were allowed to graze on vetch instead of rangeland and the supplementary feeding was adjusted accordingly. While the traditional supplementary feed was based on barley grain, wheat bran and barley straw, the improved diets included other locally available feeds like cotton seed cake, molasses, sugar beet pulp and ammoniated wheat straw. The average daily milk production of Awassi ewes in 4 out of the 5 tested diets was at least 25% higher than under control diet. Texture profile analysis (TPA) of yogurt and cheese showed a positive effect of diets on cheese hardness and yogurt firmness. In 4 out of 5 alternative tested diets, cheese hardness increased at least 9% and yogurt firmness at least 4% over the control group. As these are important characteristics used for pricing yogurt and cheese in the Middle East, the four diets show a good potential to achieve higher benefits. The sensory data analysis of cheese revealed that texture was improved in 4 out of 5 alternative tested diets, whereas the property of chewiness was improved only in 3 out of 5 alternative tested diets over the control. The measured sensory traits of yogurt were improved in 4 out of 5 alternative tested diets over the control diet. The alternative tested diets containing agro-byproducts and ammoniated wheat straw are apparently options for resource-poor farmers in the Middle Eastern region to increase their productivity and income without affecting the main quality of products.

Keywords: agro-byproducts, Awassi sheep, diet supplementation, feeding strategy, Middle East, milk yield, texture profile analysis of yogurt.

2.4.12. Effect of grazing on range plant community characteristics of landscape depressions in arid ecosystems

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Arid rangelands in Syria, referred to locally as the 'badia', cover more than half of the country. These vast, dry landscapes are punctuated by broad dry basins ('wadis'), or gentle landscape depressions that have relatively high productivity and are ecologically important as plant and wildlife refuges. This study examined the effect of two years of rest (no livestock grazing) on plant species composition, species diversity and vegetative productivity, on paired landscape depressions in northwestern Syria. Average plant density was 31 plants/m2 and 868 plants/m2, for grazed and protected depressions, respectively (P=0.001). Similarly, plant biomass was 467 kg DM/ha and 2,299 kg DM/ha, respectively, for grazed and non-grazed

sites (P=0.001). On continuously grazed sites, approximately 90% of the phytomass was harmal peganum (Peganum harmala L.), a non-palatable, toxic perennial plant. The Shannon/Wiener diversity index was 0.2-0.3 for the grazed areas, compared to 2.0-2.5 for the protected depressions. Thus, it is possible to increase the productivity and diversity of degraded landscape depressions in arid rangeland ecosystems. We suggest that rational, scientifically-based grazing systems, that balance seasonal animal consumption with plant growth, can maintain ecosystem services while providing forage for livestock.

Keywords: arid ecosystems, rangelands, grazing species diversity, landscape depressions, Syrian badia

2.4.13. Potential of triticale to mitigate impact of climate change on food security in crop- livestock systems in non-tropical dry areas

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Feed deficits, partly due to low and erratic mean total rainfall, are widespread in countries in the non-tropical dry areas of Central and West Asia and North Africa. There is need to identify accessions of food/feed crops that have high water productivity and are adapted to saline conditions. A 2-year trial compared 39 triticale accessions for forage and grain production, and forage quality at two dryland sites with varying average total annual rainfall in Tel-Hadya and Breda, northwest Syria. Significant ($P<0.05$) site x accession interaction was recorded for phonological and morphological traits; yield and yield components, and concentrations of hay and straw crude protein, acid detergent fiber, neutral detergent fiber, and in vitro organic matter digestibility. Promising accessions were identified, based on grain, hay and straw yield, and hay and straw quality as selection criteria. These accessions could be integrated into small-scale crop-livestock systems to mitigate the effects of climate change on food and feed insecurity on resource poor crop-livestock farmers in the non-tropical dry areas.

Keywords: climate change, crop-livestock system, feed deficit, triticale accessions.

2.4.14. Role of soil organic matter and balanced fertilization in combating land degradation and sustaining crop productivity

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Land degradation is a widespread problem throughout the tropics and subtropics. The extent of degraded lands in India is estimated to be around 158 million hectares. Restoration of these lands is of prime importance for economic and ecological reasons in both irrigated and rainfed ecosystems. The economic rationale for restoration of degraded soils is related to productivity and income. Important among ecological reasons are carbon sequestration in soil to mitigate the greenhouse effect, and minimizing risks of pollution, contamination and eutrophication of natural water. There is tremendous potential to sequester carbon through restoration of degraded ecosystems, and more so through reclamation of salt affected lands. The soil organic carbon (SOC) pool constitutes one of the five principal global carbon pools, the others being oceanic, geologic, atmospheric and biotic. The rate of depletion of SOC in tropical soils is exacerbated by the onset of soil degradation processes, including the decline in soil structure leading to crusting/compaction and accelerated runoff and erosion, reduction in soil biotic activity, leaching of bases, and depletion of soil fertility. Although the amount of SOC in the soils of India is relatively low, ranging from 0.1% to 1% and typically less than 0.5%, its influence on soil fertility and physical conditions is of great significance. The cause of low levels of organic carbon in Indian soils is primarily high temperature prevailing throughout the year. Soil organic carbon level reaches a fixed equilibrium that is determined by a number of interacting factors, such as precipitation, temperature, soil type, tillage, cropping systems, fertilizers, the quality of crop residues returned to the soil, and the method of residue management. Conversion of land from its natural state to agriculture generally leads to losses of SOC. It may take up to 50 years for the organic carbon of soils to reach a new equilibrium level following a change in management, but this period is much shorter in a semi-arid and tropical environment like India. Considering the nutrient removal by crops, and supply through different sources under intensive cropping systems, it is seen that removal is far greater than the supply. It is therefore extremely important to maintain SOC at a reasonably stable level, both in quality and quantity, by adding organic materials from crop residues. Long-term experiments conducted in different agro-ecoregions of India involving a number of cropping systems and soil types, have proved that even balanced use of NPK fertilizer helps in maintaining SOC. The encouraging results obtained by the integrated use of fertilizers, organic and green manures, and bio-fertilizers, are providing the leads for future strategies for rational use of land for enhancing productivity without detriment to the environment.

Keywords: balanced use of fertilizers, carbon sequestration, sustaining crop productivity, land degradation, organic carbon.

2.4.15. Soil carbon sequestration: can it take the heat of global warming?

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Expectations have been raised that carbon sequestration in soils could provide a short-term bridge to reduce the impacts of increasing carbon emissions until low-carbon technologies are available. This paper tackles the issue by balancing soil carbon sequestration potentials against anthropogenic CO2 emissions, as well as emissions of greenhouse gases from soils in response to global warming (+2°C) that is currently considered inevitable. Central Asia, with its vast areas of rangelands, is looked at in more detail. Therefore, organic carbon in the soils of Central Asia, and losses in response to land use, was quantified in a spatially explicit way. In conclusion, it appears that, unfortunately, the strategy of soil carbon sequestration as a stand-alone measure is not a viable bridge to a future in which alternative energy sources can substitute fossil fuel burning, but can only be part of a set of mitigating measures.

Keywords: anthropogenic CO2 emissions, carbon sequestration, Central Asia, climate change.

2.4.16. Community-based reuse of gray water in home farming

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With annual renewable water resources of less than 150 m3 per capita, Jordan is one of the most water scarce countries of the world. The demand for freshwater resources has been on the increase in the urban sector due to the economic development and population growth. The limited amount of water available for agriculture necessitates the use of non-conventional water resources, such as gray water, as an alternate option. Gray water refers to domestic wastewater generated by baths, showers, hand basins, floor wastes, washing machines, and dishwashing, which has not been mixed by toilet wastes. Its treatment and reuse offers an attractive option in arid and semi-arid regions due to its role in promoting the preservation of high-quality freshwater, as well as reducing environmental pollution. Additional benefits include cost savings to both the consumer and state water authorities, through reduced sewage flows and potable water supplies. This resource comprises about 50-80% of house water consumption in the rural areas of Jordan. In times of unpredictable rainfall resulting from climate change, gray water provides a reliable supply of water for home farming to irrigate high-value crops, contributing to food security and income generation at the household level. Gray water reuse research activities in Jordan, conducted mainly by the National Center for Agricultural Research and Extension (NCARE) in cooperation with several national and international organizations, reveal its high potential for irrigation of residential gardens, especially in rural areas. However, there is a need for further research in gray water treatment and quality improvement to reduce environmental risks and enhance sustainable use. In partnership with the International Center for Agricultural Research in the Dry Areas (ICARDA), NCARE is addressing these aspects through community-based interventions leading to safe and productive use of gray water for crop production.

Keywords: crop production, environmental risks, greywater (gray water) reuse, residential gardens, water resources.

2.4.17. The role of mycorrhizal fungi in reducing the impact of environmental climate change in arid regions

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Global environmental change is one of the greatest challenges that humanity faces today. Atmospheric CO2 is considered the major gas responsible for these changes and global warming, mainly due to the increased human activities because of rising population. Land use and land cover are also linked to climate and other environmental changes. However, less attention has been paid to the biological effects of rising atmospheric CO2 concentrations. This is especially important for the soil symbionts (e.g. symbionts of mycorrhizal fungi), which occur in most biomes on earth and are important for plant growth and development. Arbuscular mycorrhizal (AM) fungi are the most common group of mycorrhizal fungi which colonize the roots of over 80% of land plant families. Located at the plant–soil interface, AM fungi are a potentially important link in the chain of response of ecosystems to elevated atmospheric CO2. The symbiosis confers numerous benefits to host plants including improved plant growth and mineral nutrition, and tolerance to diseases and stresses such as drought, temperature, metal toxicity and salinity. AM fungi may play also a role in the formation of stable soil aggregates (through secretion of sticky glomalin) and the building up of a macro-porous soil structure that allows the penetration of water and air but prevents erosion. Through all these effects, AM fungi are helping plants to utilize the CO2 fertilization occurring due to elevated atmospheric concentrations, and as a result, increase carbon sequestration by terrestrial vegetation. As obligate symbionts, mycorrhizal fungi depend on the plant for their carbon source. As much as 20% of the total carbon assimilated by plants may flow to the soil mediated by mycorrhizae, and thus form an additional carbon-sink significant enough to enhance carbon fixation

under elevated atmospheric CO2. Through this process, the fungi might cause sequestration of carbon in agricultural soils and can help mitigate increases in atmospheric CO2. This paper provides an insight into how mycorrhizal fungi might play a role in reducing the impacts of environmental climate change in arid regions.

Keywords: arid region, climate change, elevated CO2, mycorrihza, global warming.

2.4.18. Farmers' perceptions and adaptation mechanisms to climate change in Amhara region of Ethiopia

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Amhara region of Ethiopia is at critical cross roads with a burgeoning population, a severely depressed economy, severe land degradation, and insufficient agricultural production. Added to these problems, the impact of climate variability creates challenges and imposes severe losses and hardship on poor farmers as their livelihood depends entirely on natural resources and rainfed agriculture. Farmers in the Amhara region are experiencing the effects of climate change, in: recurrent drought, seasonal shifts in rainfall, late onset and early cessation of rainfall, flooding, landslides, lowering of ground water tables, drying of lakes and ponds, development of new farmlands from the retreated lakes, lowering of the volume of river flow, drying of springs, shift of cropping patterns, the failure of high yielding crop varieties and species, introduction of new crop diseases and pests, infestation of new weed species, a rise in temperature, and an increased incidence of diseases like malaria in areas which had none before. Farmers have adopted such adaptation strategies as the introduction of early maturing crop species and varieties, construction of soil conservation structures, increased water harvesting, building diversion canals on small rivers for irrigation, use of mosquito nets, limiting livestock number, area-closure on degraded lands, diversification of livelihood sources, migration to unexplored lowland areas, and increased agro-forestry practices.

Keywords: climate change, land degradation, rainfed agriculture, soil and water conservation.

2.4.19. Afforestation as a vehicle for climate change mitigation, sustainable development and empowerment in Nigeria's drylands

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Forests provide crucial safety nets, preventing the rural poor from sinking deeper into poverty or serving as a lifeline in times of emergency. The links between forests and reduction of poverty and hunger are especially obvious in marginal areas, such as arid zones, where poverty is the greatest. Forests have been linked to livelihood security, prevention, and reversal of the environmental degradation caused by climate change, and enhanced regional development. The paper gives an overview of the Nigerian forestry sector in the dry region of Nigeria, and information on various programs and projects put in place over the years to develop the drylands of Nigeria. Afforestation programs, anchored on community participation and executed in the integrated rural development projects, will be able to control desertification, mitigate climate change impacts and create employment.

Keywords: climate change mitigation, afforestation, dry region of Nigeria.

2.5.1. The impacts of wheat improvement research on poverty reduction in different agro-ecologies in the dry areas

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Climate change is expected to increase uncertainties in agricultural production in the dry areas. The deployment of new crop varieties adapted to different environmental conditions is an adaptive strategy that can address the increased temporal and spatial variability. Drought tolerant crop varieties can be used in the drier agro-ecologies, thus reducing risk of cop failures, while high potential input-responsive varieties can be deployed in irrigated environments. However, the success of such a strategy depends on how effective those crop varieties are targeted to their appropriate agro-ecological environments. Seed multiplication and distribution companies should be fully equipped to deal with the diverse demands for crop varieties according to different agro-ecologies. Failure to make appropriate seed material available to different agro-ecologies will hamper efforts to reduce climate risks and could increase poverty, and this study demonstrates how inadequate targeting of new crop varieties can lead to higher poverty. The results of the study suggest that effective seed multiplication and distribution is a necessary condition for achieving poverty impacts in the dry areas, requiring greater efforts in assessing farmers' demands for seeds of new varieties. Climate change will only make this condition more pressing, because climatic variability is increasing in the dry areas. Lack of clearer targeting of seeds to the relevant agro-ecologies (recommendation domains) will hamper adaptation to climate change and will lead to failure in achieving expected poverty reduction.

Keywords: agro-ecological targeting, climate change, dry areas, new varieties, poverty reduction, seeds.

2.5.2. Food security through community food bank and employment generation: a case study in Kurigram district, Bangladesh

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Bangladesh is one of the most populous and least developed nations in the world, with 153 million people. About 20% of its people are poor or ultra-poor, and they face severe food insecurity every year. Eight districts in the northern part of Bangladesh are more vulnerable to periodic food deficits due to frequent floods and huge river bank erosion in the rainy season, and severe drought in the dry period, believed to be occurring because of climate change. In addition, unfavorable agricultural production cycles due to prolonged dry seasons, prevent high intensity cropping, which creates a near famine situation. Since food deficit is a recurring phenomenon in the study area due to scarcity of jobs in agriculture during the lean period, there is a necessity for creating employment opportunities in non-crop agricultural enterprises, agro-processing businesses, and off-farm services. Moreover, the provision of a physical supply of food, and its accumulation in a bank to be managed by the community (community food bank), can be a justifiable approach. Keeping all these issues in consideration, this action research was conducted. Skill development training in different trades was given to the target beneficiaries for employment generation. Field surveys revealed that the introduction of self employment opportunities to poor farmers by conducting skill development training programs in different income generating activities was enabling them to acquire necessary skills, and helping them to choose self-employment in off-farm sectors. In addition, education and advocacy programs offered to them, to introduce appropriate technologies in agriculture,was increasing their food production, and the surplus produce was being deposited in a community food bank for use during the periods of crisis. The results of the action research also showed some positive changes in the socio-economic conditions of the target beneficiaries that could be supportive, to achieve food security and alleviate poverty.

Keywords: climate change, community food banks, food security, poverty alleviation, self employment.

2.5.3. Drought mitigation in Salamieh District: technological options and challenges for sustainable development

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Syria is a largely arid and semi-arid country prone to water shortage, due in part to low precipitation and inefficient management of water supplies. With changing climates, frequent periodic droughts would exacerbate the problem of water shortage and place greater risks on livelihoods. One of the areas affected is Salamieh District located in central Syria, which relies mainly on ground water for irrigation. The Aga Khan Foundation has promoted a number of mitigation strategies through a multi-input area development approach. Three strategies are specifically discussed in this paper: (i) increasing the efficiency and productivity of irrigation water through adoption of modernized irrigation and ground water monitoring; (ii) facilitation of access to new drought tolerant barley varieties, and (iii) raising awareness of livestock owners about the use of new and improved feeding techniques in conjunction with new forage varieties to improve livestock productivity and animal health. Through farmer-farmer transfer of new technologies and facilitating access to group loans, there have been a number of notable success stories in Salamieh District, such as the high adoption of modernized irrigation technologies, and planting of new drought tolerant barley varieties, that have led to higher economic returns and lower risk. Despite positive gains, there still remains concern over whether improvements in water productivity are offset by policies and choices that increase water depletion.

Keywords: adoption of drought tolerant seed, feed techniques, groundwater monitoring, modernized irrigation, Syria.

2.5.4. Climate change demands refocusing the research agenda for food security in Central Asia and the Caucasus

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The Intergovernmental Panel on Climate Change (IPCC) predicted in 2007 that average temperatures in the Central Asia region could increase 3.7°C by 2100. Such a change will have a profound influence on the whole agro-ecosystem by affecting environmental and various other components of the production system. It will also severely reduce the population of pollinating insects on which the productivity and regeneration of economically important plants depends. Climate change is going to particularly affect the livelihoods of landless rural people. For sustainable livelihoods and production under changing climates, there will be a need for reprioritizing and refocusing agricultural research in the CAC region, particularly targeting the landless and women, who had remained neglected so far as research had been focused on farmers that owned land or livestock. A number of key areas are suggested: (a) new research methods to more precisely assess the adverse impact of climate change on various components and the functioning of production systems, including pollinating insects, so that appropriate interventions to cope with the impacts can be developed; (b) more intensified research on plant genetic resources, especially of aromatic herbs and medicinal plants; (c) livestock research to enhance small ruminants’ endurance of long periods of water deprivation and exposure to high temperatures; (d) integrated research on improving ecosystem resilience and the livelihoods of people dependent on such ecosystems; (e) research to generate employment opportunities for the landless to prevent migration from rural to urban areas, and to empower women and enable them to become role models in livelihood diversification through the use of high value crops and value chains. Such a refocused and reprioritized research agenda will have to be conducted in partnership with end use stakeholder, and linkages will have to be established or improved with development agencies and civil society partners to ensure broad impact.

Keywords: CAC region, climate change, ecosystems resilience, high altitude region, livelihoods, pollinators, small ruminants.

POSTER

PRESENTATIONS

3.1. Adaptation to climate change: case studies of household level adaptation in pastoralist and agro-pastoralist communities in Borena zone, Oromiya region, Ethiopia

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This research is a part of a wider initiative to better understand the process and impact of climate change in the Horn of Africa and the Sahel. Ethiopia was selected for the research to represent the Horn. The goal is to strengthen the resilience and the adaptive capacities of vulnerable pastoral and agro-pastoral communities in Ethiopia. It is expected that the research will improve humanitarian and development policies, programming and responses to tackling climate variability, and a change in vulnerable communities. The specific objectives are to improve the understanding of local situations and processes, and to recommend pertinent policy and programmatic responses, considering evidence-based analysis. In order to meet these objectives, the research team employed qualitative research methods and tools. Focus Group Discussions (FGDs) was the principal tool, coupled with key informant interviews with community leaders. Accordingly, a total of 51 FGDs were conducted in four villages, in which 345 community members participated (44% women). The age of FGD participants ranged from 17 to 96 years old, which allowed the capture of a wide range of observations and experiences from past and present. Oral testimonies were also collected from community members including leaders, to understand the impact of climate variability and changes on households. Semi-structured interviews were also conducted in their locality, and the team collected a total of 40 oral testimonies (43% women). The results are presented in this poster.

Keywords: adaptation to climate change, Ethiopia, Horn of Africa, pastoralist and agro-pastoralist communities.

3.2. Climate change effects in Jordan: a disaster management prospective

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Jordan's water resources were already challenged well before concerns were raised over the effect of global climate change on precipitation level in the dry areas. Now that it is certain that climate change is occurring and that temperatures in Jordan are rising, the quantity of water basins and surface runoff will decrease, which can have significant impact on rainfed agriculture, the livestock sector, and overall food production. The United Nations Climate Change Conference in Copenhagen, held in December 2009, was expected to yield a climate change deal, building upon the first phase of the Kyoto Protocol, an international and legally binding agreement to reduce greenhouse gas emissions worldwide that is set to expire in 2012. This study examines adaptation for climate change in Jordan in the disaster management prospective: preparedness, mitigation, and recovery.

Keywords: adaptation to climate change, rainfed agriculture, water resource scarcity.

3.3. Seed priming enhances germination and seedling growth of pepper under drought conditions

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Soil moisture deficiency is going to be accentuated in many dry areas because of climate change. Sub-optimal germination and subsequent poor seedling establishment and growth are the major problems owing to low soil moisture. The effect of seed priming to overcome such adverse effect of soil moisture deficiency was studied on pepper (Capsicum annuum L.) (Yolo Wonder CV.). Seed were primed in five different priming agents, and were germinated both under laboratory and nursery conditions using different water potentials. Results indicated that seed priming proved to be an effective technique in improving seed germination and seedling growth of pepper, alleviating the harmful effects associated with drought stress. Differences between priming agents in this regard were observed and are reported in the poster.

Keywords: drought, germination, pepper, soil moisture stress.

3.4. Reducing nitrogen input in the sorghum-wheat system to address climate change: the effect of nitrogen and potassium interactions

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Globally, agriculture contributes 65-80% of the total nitrous oxide (N2O) emissions, mainly from the use of nitrogenous fertilizers on cultivated soils. Almost 90% of the global atmospheric N2O is formed during the microbial transformation of nitrates and ammonium ions in soils and water. Application of nitrogen, without balancing it with other essential plant nutrients including potassium, may accelerate the generation of N2O (and NO) and contribute to the greenhouse effect and climate change. The present study is based on the hypothesis that balanced fertilization in the sorghum-wheat system may possibly result in a more efficient uptake of mobile nitrogen in the soil, and thus may reduce the potential risk for N2O emissions and nitrate leaching in ground water. An experiment was conducted during the 2007/08 cropping season on a sorghum-wheat cropping system to study the interactive effect of N and K on the leaching of nitrate, using PVC-drums filled with a 100 cm column of garden soil on a 10 cm layer of gravel. Combinations of four rates of urea nitrogen (0, 90, 120 and 240 kg N/ha) and four rates of KCl potassium (0, 30, 60 and 120 kg K/ha) were tested. Phosphorus at 60 kg P/ha as single super phosphate, and zinc at 25 kg ZnSO4.7H2O/ha were applied uniformly to all the treatment combinations. The PVC-drum had a drain at three different depths (30, 60 and 100 cm of the soil column). Plastic funnels (approximately 10 cm in diameter) with PVC tubes (5 mm diameter) were fitted to each drain to collect the leachate. The nitrate content in the leachate increased with increases in N levels, while it significantly decreased due to K application at all collection periods and depths. Minimal nitrate content in the leachate was observed with the combination K60 × N120 , which was 3.86% at anthesis. Potassium application at 60kg/ha could thus help in sustaining crop growth and productivity of sorghum and wheat, and reduce the nitrate load of soil solution, which would help in reducing N2O emissions to the atmosphere.

Keywords: balanced fertilization, nitrate leaching, greenhouse gas emissions.

3.5. Environmental impacts of oil and gas production in Nigeria

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Energy and a good environment are essential for sustainable development. Hence there is growing demand for energy to power economic development but with technologies that are cost effective and that permit sustainable energy production. In Nigeria, petroleum oil and gas production for meeting energy demands is causing environmental degradation and while most people lack access to clean and affordable energy. There are issues of climate change, loss of biodiversity, and ozone layer depletion, because of the exploitation of non renewable sources of energy. This paper addresses these issues and how they can be effectively managed through innovative policies and partnership with organizations that can help pilot projects that will build a sustainable energy production system in Nigeria.

Keywords: environment, oil and gas production, sustainable energy production, Nigeria.

3.6. Interactions between land-use and ecosystems under climate change: regionalization of empirical findings

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Vegetation is considered as a biotic indicator that is sensitive to climate changes. The Mediterranean region is unique in the world from the standpoint of plant genetic resources and plant diversity, as agriculture is said to have first started here. The region is one of the most important centers of diversity for a number of globally important crop plants, including many cereals, food legumes, vegetables, forage plants, fruit trees and nuts. It is estimated that one third of household food and livelihood security comes from the diversity and the richness of the Mediterranean flora. At least, 25,000 species of higher plants are recorded in the region, a high proportion of which are endemic. Unfortunately, there is a lack of information about the effect of climate change on the biodiversity in Jordan that represents arid and semi-arid conditions in the Mediterranean region. This information is of crucial importance for planning the use of genetic resources and protecting them from the threat of adverse climate change. This study assesses the vegetation distribution in the Wadi Shueib area of Jordan, and investigates the relationships between plant species distribution and different climatic variables such as temperature and rainfall under possible climate changes.

Keywords: biodiversity, Jordan, Mediterranean region, vegetation distribution.

3.7. Organic agriculture as a climate change mitigation strategy and food security option for rural communities in drylands in northern Nigeria

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Organic agriculture, as a mitigation strategy in stemming the impact of climate change, is a proven option adoptable by dryland communities. Based on closed nutrient cycles, biodiversity and effective soil management, organic farming involves the use of recycling, crop rotation, green manures, composting, biological pest control, and strictly

limits the use of synthetic fertilizers, pesticides and plant growth regulators. There is little or no loss of resources, which makes the environment self sustainable. Though dry areas tend to be difficult to manage effectively due to inadequate rainfall, organic farming is less susceptible to variations in rainfall. And with improved irrigation systems, farming is possible with increased yields. Thus, an adaptation and mitigation strategy can be developed on an established practice, because organic farming as a means of livelihood has been developed in different climatic zones of the world. Financially, organic agriculture as a mitigation strategy is cost efficient because of the fact that the natural ecosystem comes into play. This poster discusses various practical strategies with a detailed analysis of how organic farming can help combat climate change and improve the quality of lives of people living in dry areas of the world.

Keywords: climate change, mitigation, organic agriculture, rural communities, recycling, livelihoods.

3.8. Assessment of pigeonpea genotypes (*Cajanus cajan*) for drought tolerance in central India

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India accounts for about 77% of the world area of pigeonpea (Cajanus cajan L. (Millsp)). It is an important source of protein in the daily diet of people, especially in central India. The crop is mainly grown on marginal lands in central India, which is a major pigeonpea growing belt, under rainfed conditions, and often suffers from moisture stress at the late pod filling stage. With climate change, the frequency and severity of drought is increasing. This study was conducted to assess the drought tolerance of newly developed pigeonpea genotypes in central India to identify sources that can be used in a breeding program for drought tolerance. Root length, root spread, root/shoot ratio, root biomass, moisture retention of leaves, rate of water loss, relative leaf water content, membrane injury and high relative yield under water limited environments can serve as important indices for the evaluation of drought tolerance of the genotypes. Stability of some of these traits across locations was investigated, as these can provide a tool for selection of suitable genotypes. Under terminal moisture stress conditions, BRG 2, TTB 7, BSMR 736, JSA 59 and PT 25-6 proved promising at Bangalore Center in Karnataka; JSA 59, PT 25-6, BSMR 736, GT 101, JKE 206, WRG 42 and GTH 1 at S.K.Nagar Center in Gujarat; and PT 25-6 and BRG 2 at Khargone Center, Madhya Pradesh. Based on these studies, it is concluded that BRG 2, TTB 7, BSMR 736, GT 104, JSA 59, PT 25-6, WRG 42, JKM 189 and JKE 206 are suitable sources for incorporation of tolerance against terminal drought stress in high yielding pigeonpea varieties.

Keywords: pigeonpea, drought tolerance breeding, selection index, central India.

4. COMMITTEES FOR THE INTERNATIONAL CONFERENCE ON FOOD SECURITY AND CLIMATE CHANGE IN DRY AREAS, 1-4 FEBRUARY 2010, AMMAN, JORDAN

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