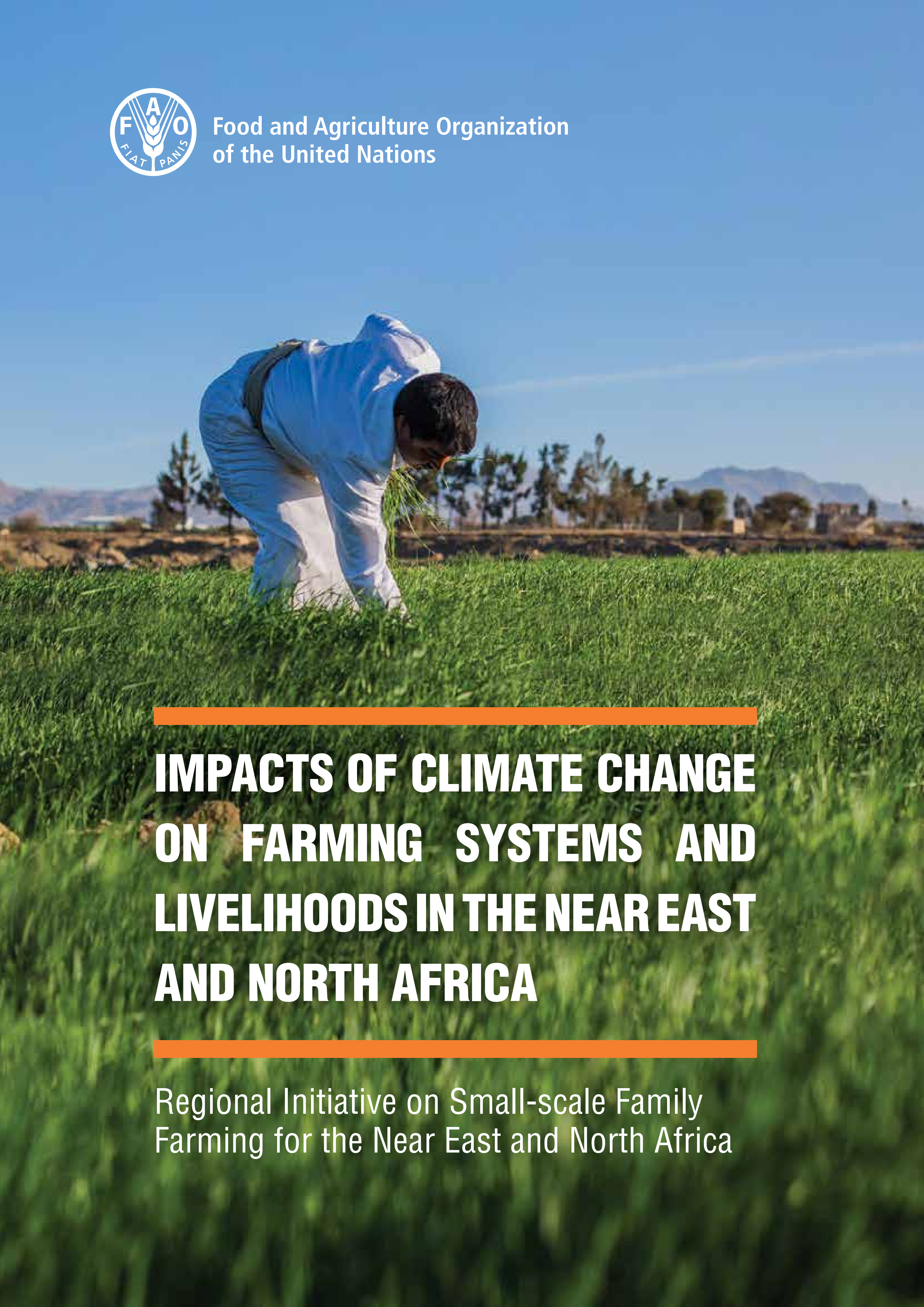

Food and Agriculture Organization
of the United Nations

IMPACTS OF CLIMATE CHANGE ON FARMING SYSTEMS AND LIVELIHOODS IN THE NEAR EAST AND NORTH AFRICA

Regional Initiative on Small-scale Family Farming for the Near East and North Africa

IMPACTS OF CLIMATE CHANGE ON FARMING SYSTEMS AND LIVELIHOODS IN THE NEAR EAST AND NORTH AFRICA

With a special focus on small-scale family farming

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COVER PHOTOGRAPH

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Foreword

Achieving the Sustainable Development Goals of eradicating poverty (SDG 1), hunger (SDG 2) and clean water and sanitation (SDG 6) is not possible without directly addressing the impacts of climate change (SDG 13). Agriculture and food systems are on the forefront of this challenge and nowhere is this more evident than in the Near East and North Africa (NENA) region. Climate change is projected to increase temperatures and extreme weather events and reduce precipitation and weather predictability. While there will be variations based on local specificity, this will result in a general reduction of the production and productivity of both crops and livestock throughout the farming systems in the NENA region. These trends result in two interrelated challenges.

First, this will have major implications for hunger and poverty reduction given that 60 to 70 percent of the region's poor live in rural areas that are dependent on agriculture. Second, that small scale farmers supply around 80 percent of the region's agricultural production means that their ability to produce is directly correlated with the food security of the region. In this context, the impacts of climate change act as a risk-multiplier in a vulnerable region that is already hard pressed to maintain its food security because of a mixture of challenging factors, including natural resource scarcity, comparatively low agricultural productivity, and conflicts. These constraints are then met with rising consumer demands as the region's population grows and becomes more affluent.

Small-scale farmers' livelihoods are at risk due to their direct dependence on natural resources. Currently, these farmers are amongst the poorest and most marginalised in the region. They are disconnected from resources, markets, extension services and social protection systems, making them even more vulnerable to the impacts of climate change. Further, small-scale farmers that are currently living on the margins of productivity could be pushed over the edge. As such, the implications of climate change on small-scale farmers reaches deep into the very socio-economic fabric of the region. This will be the case especially as changing agricultural productivity reduces options for sustainable rural livelihoods, thereby creating incentives for distressed migration. Supporting these farmers to manage their production and productivity in a changing climate will therefore be essential alongside developing income diversification options to ensure sustainable livelihoods.

Given that they are the main domestic agricultural producers, the impacts of climate change on small-scale farmers extends beyond the farm to the food security of the region. This makes it even more important for policymakers to determine the most effective ways to support small-scale farmers to ensure that agricultural production and productivity can be managed under changing climate conditions and increasing uncertainty. Some areas will likely be shifted out of productive zones, which suggests that it will also be important to consider the impact these changes will have on agricultural investments and agricultural transformations.

Aware of this challenge, the governments of the NENA region have prioritised climate change at the FAO Regional Conferences for the Near East, most notably in 2012. In the regional report on NENA small-scale family farming trends that was subsequently developed by the Regional Initiative on Small-Scale Family Farming, the ability to adapt to climate change was identified as one of the major challenges facing these farmers. It was then the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) that provided the necessary climate change data.

In this context, this report aims to bring the findings of these two branches of work together to understand the implications of climate change for a key vulnerable group in the region. In so doing, it aims to bridge the gap between science and policy to create an understanding of where and how this research can be practically applied. It also aims to provide a high-level overview of the potential impacts of climate change on small-scale farmers to set a framework for more in depth analysis at the national and sub-national levels. This report is the first regional-level assessment that examines such impacts devolved to the farming system level using Climate Impacted Farming System (or CIFS) maps. It is important to generate this regional understanding to draw out common trends and identify priority areas for addressing climate change in the region.

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This study has been developed under the Regional Initiative on Small-scale Family Farming by Phoebe Lewis (Agronomist) and Mohamed Abdel Monem (Water and Environment Specialist), under the supervision of Alfredo Impiglia, Delivery Manager for the Regional Initiative on Small-scale Family Farming, FAO Regional Office for the Near East and North Africa (RNE).

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Executive Summary

The Near East and North Africa (NENA) is one of the regions that will be most affected by the impacts of climate change. Small-scale farmers are amongst the most vulnerable communities to these impacts because of their direct dependence on climate and natural resources, relative poverty, and often poor access to support systems and safety nets. Previous research on the impacts of climate change in the NENA region has focused on general adaptation measures that are necessary and appropriate for the region, or focused on specific issues like water, livestock or institutions. However, no study to date examines the impacts of climate change on the whole farming system that includes land, water, crops, livestock, and those at the heart of the challenge in the region: small-scale farmers.

This report draws out the major trends affecting agriculture, in the NENA region and the general implications for small-scale farmers before delving into an integrated analysis at the farming system level. Using temperature and precipitation data from the RICCAR (2017) report, this study has developed Climate Impacted Farming System (CIFS) maps that demonstrate what the projected temperature and precipitation changes will be for the farming systems of the region by the mid-century (2046–2060) in a moderate and worst-case scenario. These CIFS maps – along with other relevant climate change information – are applied for all the major areas of the region where agriculture is conducted: the Maghreb, the Mashreq, North and West Iran, the Nile Valley (Egypt and Sudan), and Yemen to determine the implications that climate change will have for small-scale farmers. In so doing, they identify potential hot spot areas for agriculture under a changing climate.

The report finds that the climate change trends for the region will result in the direct risk of reduced production and productivity for small-scale farmers and the indirect risk of endangered livelihoods for these farmers, especially if there are limited options for diversification. Overall, small-scale farmers in rain-fed mixed farming systems are likely to be the most severely impacted by the effects of climate change. This is partly due to these systems' dependence on precipitation patterns that are generally projected to reduce in quantity and increase in unpredictability. In particular, wheat – the main staple crop for the region – and barley are projected to suffer yield losses in most of the farming systems. Given that wheat is used for direct consumption by the farmers as well as being sold along value chains, this will have serious implications for the food security of these farmers as well as those dependent on them. Fortunately, most small-scale farmers already use integrated crop-livestock systems that increase their adaptation capacity to climate change.

In particular, for the rain-fed mixed farming systems, cereal, horticultural and perennial crops will see reduced yields. This is especially compromising for high-value crops such as olives, which are projected to decrease 65–90 percent under RCP 4.5 and by more than 90 percent under RCP 8.5 by the end of the century throughout the region (FAO et al., 2017). The changes to these cash crops will jeopardize the livelihoods of these small-scale farmers. Some resilience is provided through their on-farm diversification. For instance, many farmers

keep goats and sheep, which are the least vulnerable livestock to the impacts of climate change. Despite this, farmers will need to look towards diversification both on and off the farm to assuage the worst impacts.

The impacts on highland mixed farming systems are similar, with wheat production observing notable losses. Highland mixed farming systems are also more vulnerable to flooding and the associated soil erosion that can further reduce crop yields. Livestock are also likely to deliver reduced dairy milk yield relative to feed. This is mostly for goats and sheep, which constitute the majority of ruminants. While dryland mixed farming systems also witness crop yield declines, their very nature exposes them to the risk of transforming into rangeland. This jeopardizes the income of the farmers in these lands in both the Libya and the Mashreq where these systems prevail. As with the other systems, the mix of livestock and crop cultivation provides some resilience to these farmers. The irrigated farming system that dominates parts of Egypt, Iraq and Sudan will see crop yield declines for both wheat (in the case of Egypt) and rice (in the case of Iraq) as well as horticultural crops. Irrigated farming systems in the region currently engage in highly water-inefficient practices that need to be optimised as the demand for irrigation grows in a changing climate. Goats and sheep – that are the least vulnerable livestock group to climate change – dominate the pastoral systems in the NENA region. Nevertheless, reduced animal feeds, increased animal heat stress and increased risk of infection and disease will affect animal production and productivity. This may necessitate increased movement to find better grazing land as well as diversification into non-agricultural income sources.

There are several opportunities to address climate change for small-scale agriculture. These opportunities will vary from one farming system to another. They include reinforcing on-farm capacity (both to enhance labour and agricultural productivity) and assets, diversifying on-farm and off-farm activities, developing social protection systems that enhance resilience, and managing the non-climate stressors at the technical and policy levels. Beyond these, measures specific to the farming systems in each area are outlined in the report. In some cases, the option of moving out of agriculture, or radically changing the production system, will also need to be considered.

In addition to the direct risks for small-scale farmers, the limits to their productivity and production in the context of climate change have broader implications for the investment decisions of governments or the private sector to ensure national food security. In evaluating the different policy and investment opportunities, governments will need to consider the implications that these policies will have for small-scale farmers and their livelihoods, as well as for the national food security strategies.

INTRODUCTION

The Near East North Africa (NENA) region is exposed to a series of interconnected challenges that affect agriculture and therefore food security and poverty reduction. The economic growth rate in the NENA region has stagnated at two percent per year since 1990. Meanwhile, unemployment rates remain high, especially amongst youth with 28.2 percent unemployment in the Middle East and 30.5 percent in North Africa (MEII, 2018). These trends present challenges for the region, especially given its high population growth rate, which is at 2 percent per year compared with 1.2 percent globally (FAO, 2012). While the population is growing, the unemployment rates suggest that the transition towards inclusive economic growth has not taken hold.

Around 43 percent of the NENA region's population live in rural areas, which in turn are highly affected by the poverty that results from exclusion from the region's economic growth; 70 percent of the region's poor currently live in rural areas and are largely dependent on agriculture for their livelihoods. There is a higher prevalence of rural poverty in farming systems and household economies typically encountered in highlands, drylands and pastoral systems. Of these, small-scale farmers with limited access to irrigation sources and net food buyers are amongst the poorest in the region.

Small-scale farmers face a series of challenges, to which climate change will be risk-multiplier. They include poor natural resource management (especially of water and land), limited land tenure security, small farm sizes, low technological access, low market access and limited investment (Morton, 2007). Of the various agricultural communities, it is small-scale farmers who will be disproportionately impacted by climate change. This is partly due to their direct dependence on natural resources and detachment from the extension services and social protection systems that could enable them to build their capacity and resilience.

It is the small-scale farmers who live in rain-fed areas or female-headed households that are likely to be the most dramatically impacted along with pastoralists, farm labourers and landless. Nevertheless, the impacts will be locally specific and difficult to predict (Morton, 2007). In addition, part of the challenge in estimating the impacts of climate change on small-scale farmers is that there is no unanimous definition of this group. Nevertheless, analysis of the impacts of climate change at the farming system level regarding crop and livestock production and productivity, as well as the implications that this has for the livelihoods of those dependent on them, will elucidate some of the common trends and challenges.

While it is important to understand the impacts of climate change on small-scale farmers to ensure they can transition out of poverty and hunger, there are also broader implications for the food security of those living in the region. With around 40 percent of the region's overall food supply coming from imports, this region is highly dependent on international markets and is susceptible to the price fluctuations that are likely to arise as agricultural production globally becomes less predictable (Marty, 2015). Of the remaining food supply requirements, 80 percent of this comes from small-scale farmers. Therefore, it will be essential to ensure that they have conducive conditions for crop and livestock production if the food security of the region is to be ensured.

In the context of these interconnected challenges, this report aims to provide the first regional assessment of the impacts of climate change for small-scale farmers in the NENA region as well as some opportunities for managing those risks. In so doing, it combines the output of the first downscaling of IPCC climate change projections in the region (RICCAR, 2017) to the regional research conducted on small-scale farming in (FAO, 2017), and the uses the delineation of farming systems identified in FAO (2002) as a basis for assessment of the impacts.

METHOD

The method used consists of (i) identifying major farming systems; (ii) defining small-scale farmers; (iii) using a specific conceptual framework; (iv) using data to generate maps; and (v) conducting an uncertainty analysis.

Identifying major farming systems

There are five major farming system types in the NENA region that are examined in this report. Their diversity across countries are described below with an overview of the land area, agricultural population and principal livelihoods outlined in Table 1. These data were generated for an FAO (2002) report that sought to deliver a comprehensive overview of farming systems across the world. The description of these farming systems lays the basis for the analysis in this report. In addition to the five major farming systems, there is also one large category made of predominantly desert area (sparse arid), and two more localised systems: coastal artisanal fishing and urban-based agriculture (Table 1).

Water is the main factor that determines the major types of farming systems, their diversity in the NENA region and consequently the livelihood of the inhabitants dependent on them. In NENA, there are irrigated, highland mixed, rain-fed mixed, dryland mixed and pastoral farming systems. Sparse (arid) land – which is primarily used for nomadic pastoralism – covers the rest of the region. In fact, 62 percent of the land area for the region is sparse (arid), followed by pastoral land (23 percent) and highland mixed (7 percent). Despite the extensive land area covered by sparse (arid) and pastoral land, it is in highland mixed (30 percent), rain-fed mixed

(18 percent), irrigated (17 percent), and dryland mixed (14 percent) farming systems that the largest proportion of the agricultural population lives (Table 1) (FAO, 2002).

Table 1: Major farming systems of the NENA region (FAO, 2002)

	Farming Systems	Land Area (% of region)	Agricultural Population (% of region)	Principal Livelihoods
1	Irrigated	2	17	Fruits, vegetables, cash crops
2	Highland mixed	7	30	Cereals, legumes, sheep, off-farm work
3	Rain-fed mixed	2	18	Tree crops, cereals, legumes, off-farm work
4	Dryland mixed	4	14	Cereals, sheep, off-farm work
5	Pastoral 23	23	9	Sheep, goats, barley, off-farm work
-	Sparse (arid)	62	5	Camels, sheep, off-farm work
A	Coastal artisanal fishing	-	1	Fishing, off-farm work
B	Urban-based	-	6	Horticulture, poultry, off-farm work

Mauritania is primarily sparse (arid) with agro-pastoral farming systems along its southern border. The Maghreb coast is dominated by rain-fed mixed farming systems and, slightly further inland, dryland mixed farming systems. In some cases, the dryland mixed systems also extend to the coasts. Pastoral lands then lie behind the dryland mixed farming systems in Algeria and Tunisia, whereas the two systems are primarily separated in Morocco by a belt of highland mixed farming systems. Further inland is primarily sparse (arid). This is true for the rest of the countries in North Africa up until the Nile River.

The pastoral lands extend east along the coast of Libya where they are interrupted by only a few areas of dryland mixed farming systems. The level of agricultural activity on the coast becomes relatively lower in Egypt and is still characterised by pastoral farming until the Nile Delta. The pastoral farming continues along the banks of the Nile River and into the Sinai Peninsula. The course of the river itself and the delta land are largely irrigated. This is also true for the land along the Nile River in Sudan. However, there is a far greater diversity of farming systems in Sudan. The north is largely sparse (arid), which then transitions into pastoral, agro-pastoral, cereal-root crop mixed, and root crop along the North-South gradient. Pockets of land on the eastern border are maize mixed and highland temperate mixed near the Ethiopian highlands. More extensive irrigation is observed near the confluence of the Blue and White Nile Rivers.

In the Levant, north-east Jordan is a combination of pastoral and dryland mixed farming systems, with the rest of the country dominated by sparse (arid). The West Bank and the Gaza Strip is largely dryland mixed, which extends into southern Lebanon and south-west Syria. The majority of Lebanon is rain-fed mixed farming system. The gradient changes from west to east across Syria, with the coastal area rain-fed mixed extending into dryland mixed in the northern part of the country. A belt of pastoral land extends south-west to north-east, leaving south-eastern Syria as sparse (arid) land.

Iraq is primarily irrigated along the land between the Euphrates and Tigris Rivers. A combination of pastoral, dryland mixed and rain-fed mixed farming systems are present in the agriculturally active area in the north-west of the country (Jezira area). Highland mixed farming systems are present along the Iranian border.

In Iran, highland mixed farming systems dominate the area from the Iraqi border to the Zagros Mountains as well as running along the northern border of the country close to the Caspian Sea and Turkmen border. Along the edge of this farming system lies a pastoral system that transitions into sparse (arid) land in central and south-east Iran.

Countries on the Arabian Peninsula are almost exclusively sparse (arid) with the notable exception of southern Saudi Arabia and southern Yemen that are highland mixed farming systems. Nevertheless, some rivers run along through each of the countries in the peninsula (FAO, 2002).

Defining small-scale farmers

It would be impossible to undertake an assessment of the impacts of climate change of farming systems without defining the role of those who primarily use and manage the resources of these systems: small-scale farmers. Nearly 85 percent of agricultural land holdings in the NENA region are farmed by small-scale farmers (FAO et al., 2017a). There is no universally or even regionally agreed upon definition of small-scale farmers. There is, nevertheless, some common characterisations of these farmers based on a technical dimension, property dimension and labour characterisation. The technical dimension focuses primarily on the agricultural components, namely production, output and intermediate consumption level. In addition to this characterization according to agricultural produce, there is a need to characterize the properties of these farmers. It is here that the characterisation of "small-scale" becomes important as the size of the production system is often noted regarding, for example, utilised agricultural area (UAA), turnover and standard gross production. Countries in the NENA region have different definitions and thresholds for holding size. For instance, these are absent in Mauritania and Sudan or relative in Egypt where small-scale family farming is based on land of less than three feddans. Morocco further differentiates based on rain-fed versus irrigated systems and Tunisia distinguishes based on land potential, income and investment capacity (FAO, 2017a).

Furthermore, to examine the agricultural production, productivity and property type of these farmers alone is insufficient, because the small size of their holdings necessitates a diversification of these farmers' incomes to survive. Therefore, a characterisation of labour needs to include additional off-farm (or off-system in the case of pastoralists) livelihoods such as the sale of labour in neighbouring farms or towns, processing of farm produce, handicraft production, and pendular, cyclical or longer-term migration. Labour productivity and autonomy and dependency relations inside and outside the farm holdings, including gender and/or intergenerational relations, is also important. A final element – and a key reason why examining the impacts on small-scale farmers is so crucial – is that this group is commonly one of the poorest in the NENA countries. This does not imply that all small-scale farmers are necessarily poor, but rather given an indication of their circumstance.

There is no agreed global or regional definition of small-scale farmers, and there will be variation in the farmers included from one farming system to another and between countries in this report. Nevertheless, the concept of small-scale farming coalesces around those farmers that are characteristically at or below the poverty line, that are operating on holdings that are used for informal business and/or self-consumption and in which the farmers typically undertake multiple activities both on and off-farm (FAO, 2017a).

Conceptual framework for assessing the impact of climate change on farming systems and small-scale farmers

This report brings together an analysis of both the farming systems and the small-scale farmers who depend on them to provide a holistic understanding of the impacts climate change is projected to have on them. To ensure a methodological approach is followed, this report adopted an established method developed by Morton (2007) that accounts for the impacts at the physical and socio-economic levels. Morton (2007) conducted a review of the existing literature on how to assess the impact of climate change on smallholder and subsistence agriculture and, from this, determined that a conceptual framework for understanding these should:

1. recognise the complexity and high location-specificity of these production systems;
2. incorporate non-climate stressors on rural livelihoods and their contribution to vulnerability;
3. study three different categories of climate change impacts upon smallholder livelihoods:
    a. biological processes affecting crops and animals at the levels of individual organisms or fields;

b. environmental and physical processes affecting production at a landscape, watershed or community level; and
c. impacts of climate change on human health and non-agricultural livelihoods.

This framework was deemed the most appropriate for the analysis undertaken in this report and was therefore adopted as the methodological basis. It was applied through a product developed for this report: Climate-Impacted Farming System (CIFS) maps.

Recognising complexity and high location specificity using CIFS maps

This report analyses the impacts of temperature, precipitation and other pertinent changes at the farming system level and draws interpretations of the impact that this will have on the livelihoods of the small-scale farmers dependent on these systems to recognise the complexity and high location-specificity of these production systems. The climate change indicators (primarily changes in temperature and precipitation data) are drawn from the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region report (RICCAR, 2017). This study relies strongly on the findings of RICCAR since it is the most recent, region-wide dataset that is drawn from the International Panel on Climate Change (IPCC). The models used in RICCAR downscale IPCC global result to the regional level. While not presented in the RICCAR report, data were available for Iran and were thus included to have a comprehensive analysis for the NENA region.

These data are then overlaid onto data of the major farming systems of the region, as defined in FAO's GeoNetwork (FAO, 2002). These data were last updated in 2002. However, it is safely assumed that the major farming systems will not have altered significantly since that time. In addition, for countries where it was suspected that there might have been changes since 2002, a consultation with experts in the FAO country offices was conducted. This overlay generates the specific product of this report: Climate-Impacted Farming System Maps. The justification for the choice of time period and representative concentration pathway are outlined in the section below. These CIFS maps allow, for the first time, a view of where and to what extent climate change will influence agriculture in the NENA region. In so doing, they enable an evaluation of all the major parts of the region in which farming is currently taking place.

Categories of climate and non-climate stressors

Each of these potentially impacted farming systems are then analysed using four criteria to determine the impact of climate change throughout the farming system as well as on the livelihoods of small-scale farmers who depend on these systems. Consistent with the framework outlined in Morton (2007), these criteria are the biological processes, environmental and physical processes, and impacts of climate change on human health and non-agricultural livelihoods mentioned above. They are analysed in an integrated manner. Where there is insufficient information to analyse aspects of the climate change impact categories at the farming systems level, analysis will be provided at the regional level.

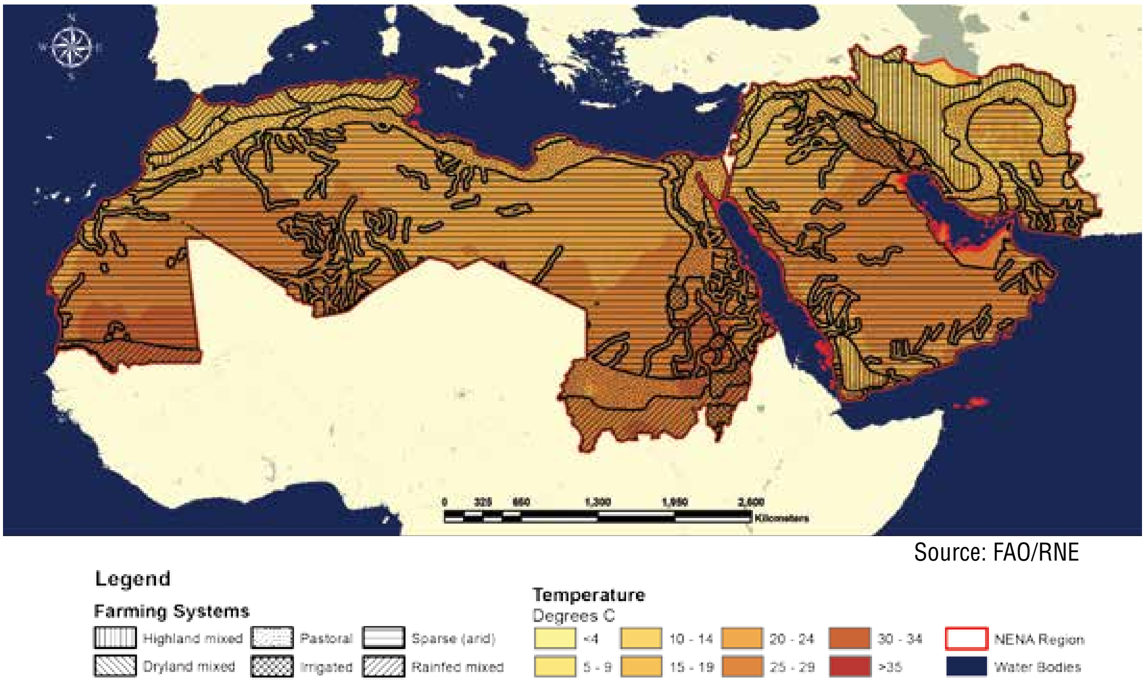
Specifically, the biological, environmental and physical processes will examine changes in temperature and precipitation primarily. Other impacts (such as sea level rise) will be examined as applicable. The changes in temperature and precipitation data are assessed for Representative Concentration Pathways (RCPs) 4.5 and 8.5 for the mid-century, representing moderate and worst-case scenarios (business-as-usual), respectively. RCPs are greenhouse gas concentration (not emissions) trajectories adopted by the IPCC in its AR5. The RCPs identify four possible climate futures, all of which are considered plausible depending on the quantity of greenhouse gases emitted into the atmosphere in the coming years. The four pathways (RCP2.6, RCP4.5, RCP6 and RCP8.5) are named after a possible range of radiative forcing values in the year 2100 as compared with pre-industrial values (i.e. +2.6, +4.5, +6.0 and +8.5 W/m2, respectively) (IPCC, 2014a). These RCPs are compared with temperatures and precipitations from a base period (1986-2005) (Figures 1, 2).

RCP4.5 assumes that greenhouse gas emissions will peak in 2040 and decline thereafter if measures are taken to reduce CO2 emissions significantly, whereas RCP8.5 assumes that emissions will continue to rise until and beyond 2100, representing the so-called business-as-usual scenario. These two scenarios – assessed at mid-century (2046–2065) – have been selected because they were deemed the most appropriate magnitudes and timescale for this report and the implications for any subsequent actions.

Finally, the impact of non-climate stressors is integrated into this analysis. Morton (2007) identifies seven non-climate stressors affecting smallholder and subsistence agriculture, including (1) population increase driving fragmentation of landholding, (2) environmental degradation caused by population, poverty and ill-defined and insecure property rights, (3) regionalised and globalised markets, and regulatory regimes, increasingly concerned with issues of food quality and food safety, (4) market failures in product marketing and input supply, following withdrawal of governments, leading to decreased market access for smallholders, (5) protectionist agricultural policies in developed countries, decline and unpredictability in the world prices of many major agricultural commodities, macro-economic shocks, (6) state fragility and armed conflict in some regions, and (7) spread of pandemics and panzootics.

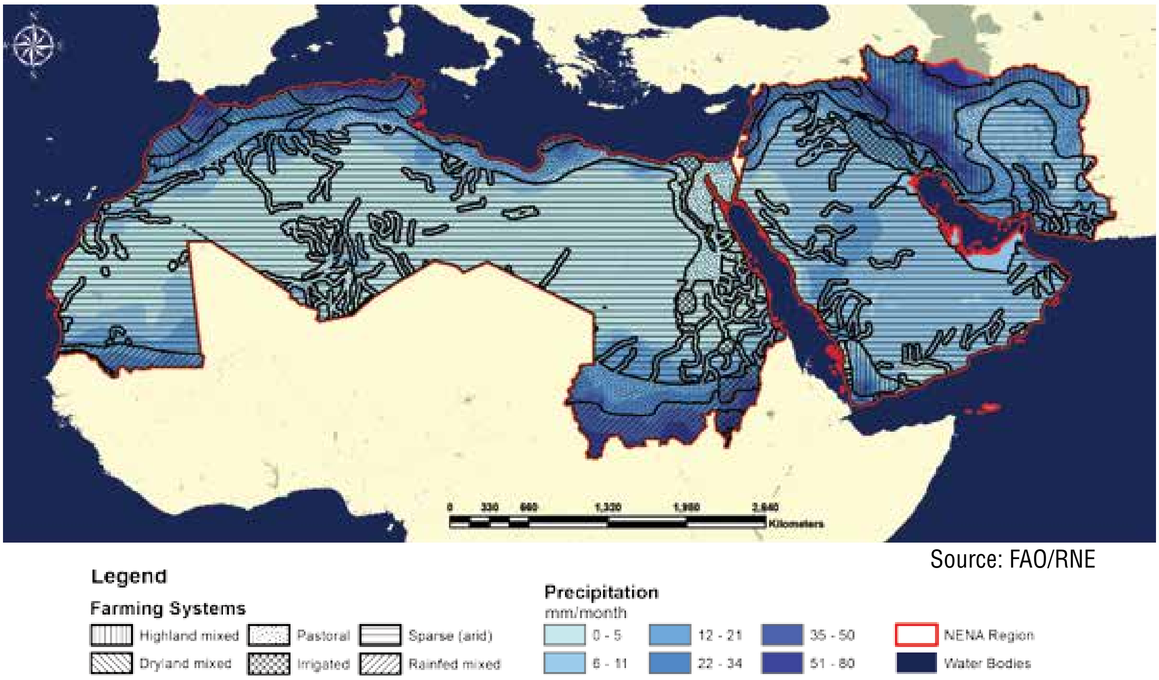
It is important to note that for the NENA region, there are factors other than population increase that are driving land fragmentation. These non-climate stressors will be analysed in conjunction with the categories of climate change impacts. Together, this will provide a comprehensive overview of the impacts of climate change on the farming systems and

Figure 1. Temperature in base period (1986-2005) with the farming systems overlaid.



Source: FAO/RNE

Figure 2. Precipitation in base period (1986–2005) with the farming systems overlaid.



Source: FAO/RNE

livelihoods of small-scale farmers.

Uncertainty analysis

All climate models have inherent uncertainty. This is partly a function of the unknowns about climate system interactions that are still being studied. The confidence in using a model to make future climate projections is increased if it is possible to demonstrate that the model is capable of accurately reproducing the past. This can be challenging if there are limited data with which to calibrate model outputs. Though by no means endemic to NENA, the availability of observed climate and water station data is limited and the distribution of quality-controlled, long-term observational sites within the region is uneven. In areas where station data are recorded, access to datasets may not be publicly available or not available in digitized form to enable use in computer-based modelling applications.

In light of this, the temperature and precipitation data underpinning this report focused on data from regional or global data sources where possible in order to harmonize and control the quality of datasets. However, this did limit the potential to adapt indicators and use data that were well elaborated in some of the countries covered. In addition, this approach can – as with all climate models – leave room for errors, which can and are addressed using bias correction. This enabled a more accurate calibration of the historically observed and model-generated outputs. Bias correction is commonly more effective for non-stochastic variables such as temperature than it is for precipitation, which is more difficult to predict precisely even if it can be statistically analysed. In general, precipitation is more challenging to model for than temperature. This tends to arise mostly from the difficulty in determining the behavior of clouds at the molecular level and therefore their reflectivity and the consequent net radiative forcing.

While these factors may limit the reliability of the climate outputs used in this report, they are sufficient for its purpose, which is to provide a higher-level overview of the situation in the region. Nevertheless, uncertainty exists in the application of these data to the farming systems. This centers on the ranges used in the temperature and precipitation data. For instance, it is challenging to determine the direct impact – and therefore indirect impacts such as livelihood implications and investment decisions – of a change in precipitation of between 6.1 and 8 millimeters per month. Nevertheless, the ranges have been reduced to the extent possible to provide the most useful analysis. Furthermore, this report followed an established method for the analysis of climate change impacts on smallholder farming, which increases the robustness of this style of integrated analysis.

CLIMATE CHANGE TRENDS IN THE NENA REGION

The Intergovernmental Panel on Climate Change (IPCC) Assessment Reports are the principal source of data on climate change trends globally. The IPCC models were run for Africa, Asia and Europe separately. Therefore, secondary analysis of these data are necessary to produce trends for the NENA region as it is divided between Africa and Asia. Such data amalgamation has been undertaken by various sources based on the latest IPCC Assessment Report (AR5) published between 2013 and 2014.

RICCAR, introduced above, was established through a project involving all the countries of the region in partnership between FAO, Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ), the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and the United Nations Economic and Social Commission for Western Asia (ESCWA). The reports of RICCAR that were launched in November 2017 focused on the change in temperatures, change of precipitation and changes in evapotranspiration. This report draws mostly on the changes in temperature and precipitation. Both temperature and precipitation trends have implications for a region that is already characteristically water scarce. Demographic changes, urbanisation, rising energy demands and the trend towards food self-sufficiency will result in a marked pressure on the chronic water shortages faced in the region.

The Intergovernmental Panel on Climate Change (IPCC) Assessment Reports are the principal source of data on climate change trends globally. The IPCC models were run for Africa, Asia and Europe separately. Therefore, secondary analysis of these data are necessary to produce trends for the NENA region as it is divided between Africa and Asia. Such data amalgamation has been undertaken by various sources based on the latest IPCC Assessment Report (AR5) published between 2013 and 2014.

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The various projections and analyses of climate change trends suggest that NENA is due to be one of the regions most impacted by climate change. Overall, the region is predicted to become hotter and drier than it already is, with an average temperature increase of up to 4.8 °C by the end of the century (RCP 8.5 upper limit) (RICCAR, 2017). Also, there will be an increase in the frequency and intensity of extreme weather events such as heatwaves, droughts and precipitation extremes. It is anticipated that the warming trend and weather extremes tendencies in NENA, a region subject to economic recession, political turbulence and upheaval, may exacerbate humanitarian hardship and contribute to migration (IPCC, 2014a).

While examining trends in the intermediate future (2046–2065) and far future (2081–2100) is important, we must also note that the impacts of climate change are already being felt in the region. For example, a combined modelling and observational assessment of the 2015 heatwave in Egypt found that human discomfort increased due to human-induced climate change (Mitchell, 2016). Furthermore, a combined modelling and observational study in the southern Levant suggests that the persistent rainfall deficit during the 2014 rainy season was made more likely due to human-induced climate change (Herring et al., 2015). Some evidence suggests that the series of droughts from 2006 to 2011 that devastated crops and livestock in this area were one of the key factors that led rural populations to migrate to cities. Contrary to common narratives, in Syria, this influx of people did not lead to a competition over resources in urban areas, but rather may have enabled a critical mass of people in the same area to mount lasting demonstrations (IIED, 2016). Nevertheless, the evidence of human influence on existing climate change events in the region – as well as the anticipated influence – frame the importance and urgency of this topic.

Temperature

There is much more certainty for the model projections of temperature than precipitation for the NENA region. The average change in temperature for RCP 4.5 shows a projected increase of 1.2–1.9 °C by mid-century. For RCP 8.5, the projected change in temperature suggests an increase of 1.7–2.6 °C by the mid-century. The range in these values is due to the variation in results according to different areas of the region. For both RCP 4.5 and RCP 8.5, the changes in temperatures become discernible between 2030 and 2040. The increase in temperatures in the mid-century projections is higher in the non-coastal areas, especially in the Sahara Desert (RICCAR, 2017).

Contrary to trends observed in other regions, the CMIP5 models that underpin the IPCC process suggest that the rate of warming is much higher during the summer season (i.e. June, July, August or JJA). Most other regions reveal a more distinct warming trend during the winter season (i.e. December, January, February or DJF). This summer warming trend is particularly significant for a region where summers are already characteristically hot and dry. The model projections demonstrate a high level of robustness, particularly during these summer warming periods. The robustness is in fact highest for the end-of-century projections, especially for the RCP 8.5 scenario, which therefore suggests overall agreement amongst these results (Lelieveld et al., 2016).

Furthermore, the number of warm days and nights may increase sharply in the region. The reference period estimates an average duration of 16 days for warm spells. The duration of these warm spells could increase by up to around 83 days per year by the mid-century and around 104 days per year by the end-of-century under the RCP 4.5 scenario. In the RCP 8.5 scenario, warm spells could increase to around 118 days per year by the mid-century and exceed 200 days per year by the end-of-century (Lelieveld et al., 2016).

Precipitation

Precipitation changes are significantly more variable across time and scenario throughout the region than those for temperature. Nevertheless, decreases in precipitation can be seen across most of NENA. There is some uncertainty about the change in precipitation trends due to climate change in the coming decades. The uncertainty in predicting precipitation is partly due to the difficulties in representing the behaviour of clouds at a molecular level and then determining the associated radiative forcing. Establishing representative measurement networks will augment the region's observation capacity and will help to verify projections.

Despite this, IPCC AR5 model projections for RCP 8.5 suggest that the Mediterranean area will become drier, which is consistent with outputs of other models. The Atlas Mountains and the upper Euphrates and Tigris Rivers also observe a reduction in precipitation (Lelieveld et al., 2016). The drying trend witnessed in the Atlas Mountains is particularly pronounced in RCP 4.5 mid-century where the Arabian Peninsula and southern Iran also observe this trend (RICCAR, 2017).

The drying trend specific to the Mediterranean area is exacerbated by a feedback mechanism that reduces soil moisture, which consequently suppresses surface cooling by limiting evapotranspiration. We do not observe this trend for the rest of the NENA region where the surface energy budget is governed by radiative rather than evaporative cooling (Lelieveld et al., 2016). Based on long-term historical data from the Jordan Meteorological Department, climatic variables are changing significantly at both the national and station level, indicating that human-induced climate change is becoming more apparent. Both the Mann-Kendall Rank trend test and linear regression trends indicate that the annual precipitation in this area tends to decrease significantly over time at a rate of 1.2 mm per year.

In contrast to the drying trend, the south-eastern Arabian Peninsula observes a moistening trend. This trend is less robust but consistent with recent observations (Lelieveld et al., 2016). Data suggest that the Maghreb sub-region as well as the Arabian Peninsula, Iraq and Syria may witness the most severe changes in precipitation (FAO, 2012). In the Maghreb sub-region, the Moroccan Highlands are dramatically affected, witnessing declines in precipitation by as much as 40 percent in the worst-case scenario (RICCAR, 2017).

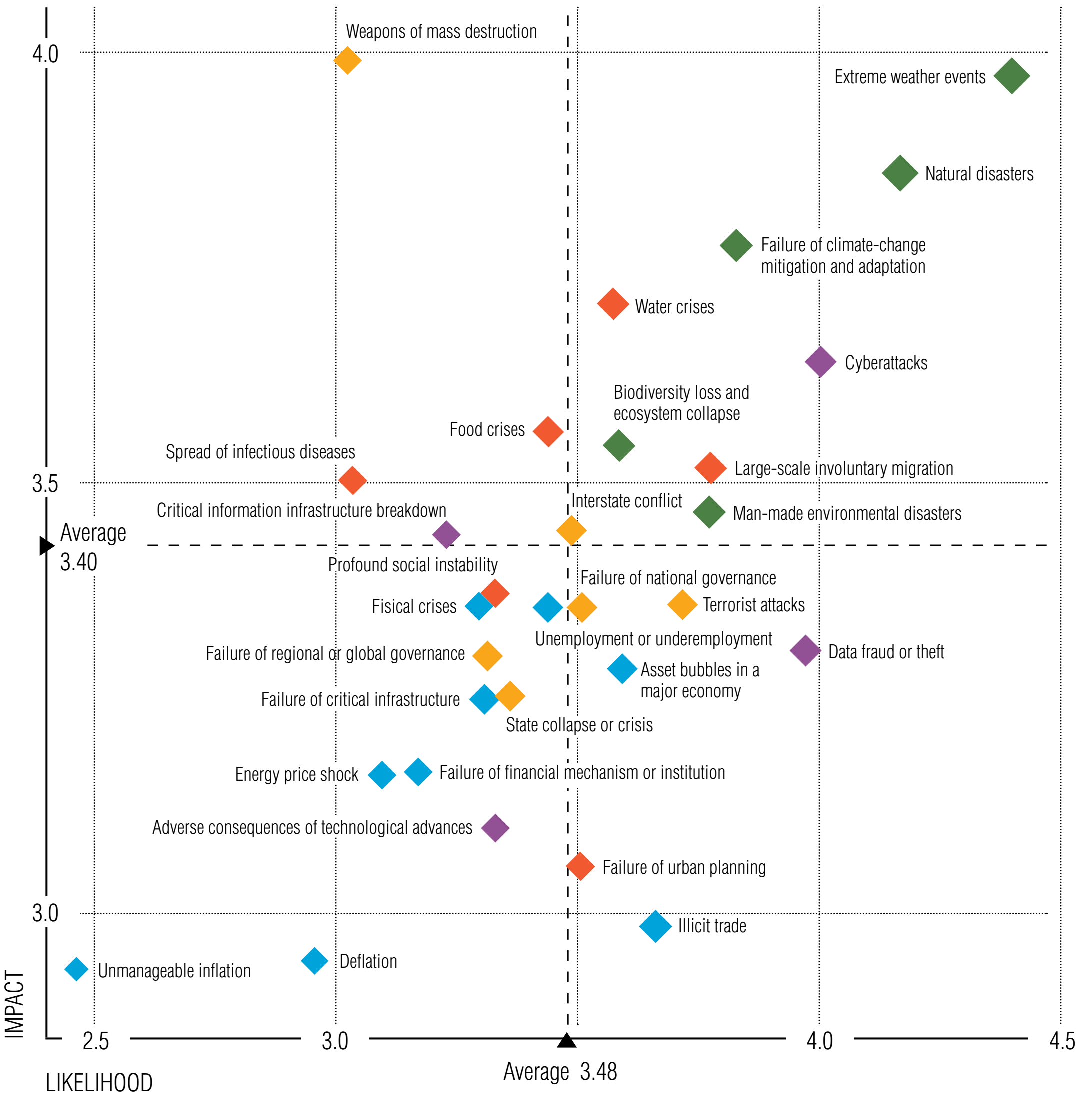
Despite a degree of uncertainty, it is evident that precipitation patterns will be altered. Given the pre-existing aridity of the region – with three-quarters of arable land already receiving less than 400 mm of annual precipitation and natural grazing lands receiving less than 200 mm of rainfall per year – any, even minor, changes in precipitation pose a serious threat to the food security and sustainability of agricultural practices (Le Houérou, 1996). These changes in precipitation patterns contribute to the hydrological model projections that reveal a decline in runoff of between zero and ten percent for most of the region by 2100 (Elbehri and Sadiddin, 2016).

Extreme Events

Extreme weather events, natural disasters, and failure of climate change mitigation and adaptation are listed as the second, third and fourth most likely and impactful global risks in 2018 after only weapons of mass destruction, according to the World Economic Forum's Global Risks Landscape 2018 Report (Figure 3) (WEF, 2018).

The region will become characterised by extreme events, including both precipitation and temperature extremes. Given the higher level of robustness associated with heat extremes, we

Figure 3. The Global Risks Landscape 2018



are justified in placing a strong emphasis on this trend and its impacts. Heat extremes have become more frequent in the region over the past decades, and the frequency of such events is predicted to accelerate in the future (Sowers et al., 2011). A trend of hot days is particularly pronounced along the Mediterranean coast of eastern Libya and Egypt in RCP 8.5 for the end-of-century. The southern Arabian Peninsula and the west coast of Africa see a significant warming trend in both RCP 4.5 and RCP 8.5. The number of tropical nights will also increase, especially in central Africa (impacting the southern parts of North African countries) and the Arabian Peninsula, which poses a significant risk to many crops that are dependent on the diurnal fluctuation in temperature to develop (RICCAR, 2017).

Both the observed and modelled extreme heat increases are not found in the CMIP5 control runs unless the radiative forcing parameter (i.e. change in atmospheric energy due to greenhouse gas emissions) is included. Therefore, the events are attributed to human-induced climate change (Lelieveld et al., 2016). RICCAR (2017) data shows an increase in both hot and very hot days, the change in which is larger than for the number of summer days, which makes sense because the number of summer days at present climate is already high for the majority of the region.

Regarding precipitation extremes, there is notable variation throughout the region. There is a general increase in the number of consecutive dry days for the Mediterranean, and western and northern Arabian Peninsula. Some areas in the central and eastern part of North Africa demonstrate a decline in consecutive dry days. In all analyses, these data should be complemented with other information because an indication of a shorter dry period does not eliminate the possibility of an increase in drought frequency occurring at the same time. Finally, the majority of the region observes an increase in precipitation intensity, except the Moroccan Highlands that show a decreasing intensity (RICCAR, 2017).

In addition to extremes, more protracted weather events are also more likely. For example, the acceleration of the hydrological cycle will increase the frequency and length of droughts, the impacts of which will be more acute when combined with other natural resource management challenges (Sowers et al., 2010).

While changes in precipitation and temperature are the most pertinent for understanding climate change in the region, other trends are also of relevance. Notably, sea level rise is predicted to affect the coastal regions of NENA. Sea level rise will increase seawater intrusion into coastal renewable and groundwater resources. The countries most at risk to the impacts of sea level rise in the region include Egypt, Kuwait, Libya, Oman, Qatar, Tunisia and the United Arab Emirates (FAO, 2012).

CLIMATE CHANGE AND AGRICULTURE SECTORS' TRENDS IN THE NENA REGION

Agriculture Sectors' Contributions to Climate Change

The overall emissions from agriculture, forestry and other land use (AFOLU) in the NENA region are low compared with other regions, but the impacts from climate change are significant. It is for this reason that this report focuses primarily on the impacts that climate change will have on the region and some of its vulnerable populations. Nevertheless, well-targeted interventions in the AFOLU sector have strong potential to deliver both mitigation and adaptation benefits (FAO, 2016a). Therefore, it is important to understand AFOLU contributions to the region's greenhouse gas emissions.

Around 69 percent of countries in Northern Africa and Western Asia, which excludes Iran and Mauritania, included mitigation targets and/or actions in AFOLU under their intended nationally determined contributions (INDCs). These targets reflect the importance of the sector in the economies of the region (FAO, 2016b). In the NENA region, agricultural production has risen steadily over the past 40 years and, due to a lack of decoupling, the associated emissions have risen in step. Nevertheless, projections suggest that there will be fewer emissions per produced unit when compared with other developing regions. Data from 2014 demonstrate that around 54 percent of the region's AFOLU emissions are from agriculture, and 45 percent come from forestry and other land use (FAOSTAT, 2018). These emissions are due mostly to changes in forest land, enteric fermentation, biomass burning, manure left on pastures and synthetic fertilisers (Figure 4). The emissions from AFOLU do not include those resulting from downstream activities along the supply chain, such as post-harvest processing, transport and distribution.

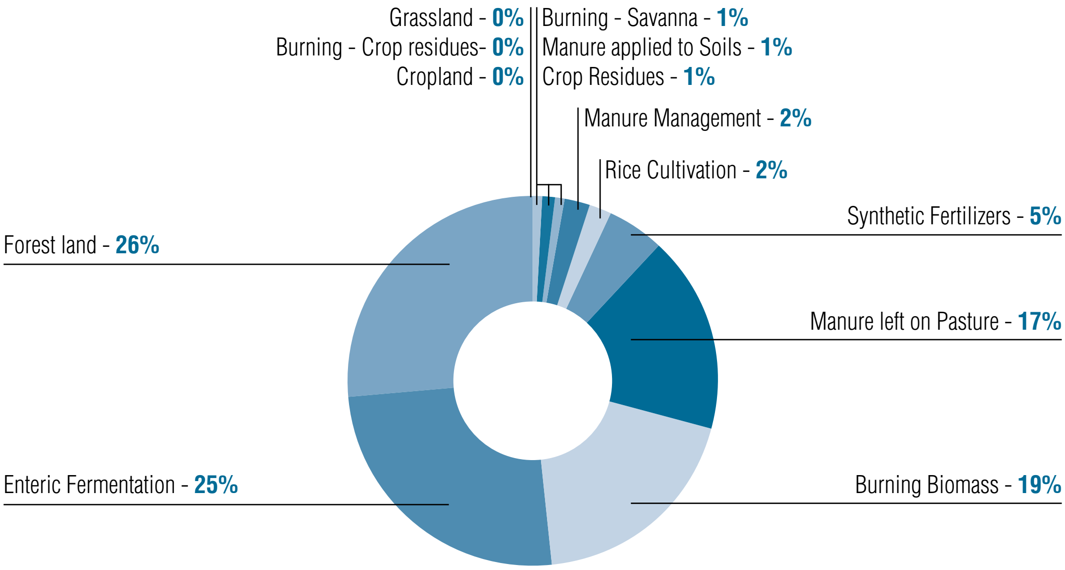
The role of small-scale farmers in contributing significantly to mitigation measures is limited. However, changes in forest land can be countered through the involvement of these farms in sustainable natural resource management (such as through agro-forestry) to stem the tide of forest degradation and deforestation for cropland and rangeland. The impact of this would be felt most strongly in Iran and Sudan. Regarding enteric fermentation, this can be managed through improved livestock productivity and somewhat through feeding practices. Further, reducing herd size is likely to become an adaptation strategy for some pastoralists across most countries in the region. Biomass burning requires measures taken at the national level, but small-scale farmers will still be contributing to this activity to clear land or convert it for other use. Therefore, there is potential for them to contribute to its reduction through sustainable land management practices. Finally, manure left on pasture is a challenge in several countries. Small-scale farmers can mitigate these emissions as part of improved crop management techniques (FAO, 2014).

Climate Change Impacts on Agriculture Sectors

Climate change influences productivity and production in agricultural sectors in a manner that will result primarily in negative socio-economic impacts. One of the main factors limiting agricultural productivity in the NENA region will be the long-term desiccation and drought that is associated with climate variability and the consequent extreme events. Overall, there will be alterations in the agro-climatic conditions. There will be temperature increases during the growing season, increases in the days above threshold temperatures and during key plant development times, increases in the length of dry seasons in already arid regions, unpredictable rainfall patterns, and salt-water infiltration due to sea-level rise. Also, hydrological and soil conditions will be impacted by decreases in groundwater recharge, surface flows, soil moisture and soil carbon. Finally, there will be increased concentrations of carbon dioxide in the atmosphere. While this may increase the photosynthesis – and therefore yields of some C3 plants such as wheat – it will reduce plant nitrogen fixation (Verner, 2012). In the ocean, rising sea surface temperature (SST) and ocean acidification (due to increased absorption of CO2) will change populations and ecosystems (FAO, 2016a).

All factors considered, climate change will limit agricultural productivity in a region that already maintains a low agricultural productivity level (Harvey et al., 2014). Similar trends will be observed in the oceans. Nevertheless, it is not solely productivity that will be impacted, but

Figure 4. NENA emissions by sub-sector.



Source: (FAOSTAT, 2018)

also post-harvest activities. This, in turn, will have ramifications throughout the economies of the region given the high dependence on agriculture. Climate shocks may lead to farmers having to sell assets or productive capital to absorb the shock. Further, willingness to invest will decline, which will pose a challenge for small-scale farmers in particular because they have limited access to credit and insurance (FAO, 2016a). These forces will influence all four aspects of food security: availability, access, use and stability (WFP and ODI, 2015). In several countries in the NENA region, the higher frequency and intensity of droughts and extreme events could lead to crop failure and food insecurity, leading to greater challenges in addressing malnutrition, famine and starvation (Elasha, 2010).

Crops

The IPCC AR5 worst-case scenario (RCP 8.5) projects a 10 to 20 percent reduction in NENA crop yields by 2050. These impacts on yields are projected in parts of the region that already experience high levels of food insecurity (FAO, 2016a). Wheat and sorghum – both major crops in the region – are highly vulnerable to the impacts of climate change. Despite its low water requirements, barley (also a major crop in the region) will also be impacted. Maize production will be reduced by rising temperatures throughout the region. Yields of several economically important fruit species – such as apples, pomegranates, olives, pistachios and other nuts – may also diminish or fail completely if winter temperatures are too high (FAO et al., 2017). Olives – also key sources of income in the region – are increasingly vulnerable as the number of days above threshold temperatures rise (Verner, 2012).

Livestock

Pastoralists are amongst the most vulnerable groups to the impact of climate change in the region, largely due to their limited adaptive capacity. The only notable exception to this exposure may be pastoralists living in mid-latitudes where higher temperatures could lead to richer pastures and increased livestock production (FAO, 2016a). Oman, Libya, Mauritania, Sudan, Qatar and Yemen are in particularly precarious positions, with 70 to 80 percent of livestock population vulnerable to the impacts of climate change. Nevertheless, 30 to 50 percent of livestock populations in other countries in the region are also vulnerable (van de Steeg and Tibbo, 2012).

The impacts of climate change on livestock focus on animal productivity, animal health and biodiversity, the quality and amount of feed supply, and the carrying capacity of pastures (van de Steeg and Tibbo, 2012). Overall, animal production may decrease. Indeed, a reduction of 25 percent in animal production is estimated to result solely from reduced feeds and increased heat stress. Higher temperatures could also reduce dairy milk yield in relation to feed (Verner, 2012). In addition to production, productivity of livestock, such as reproductive functions and/or milk production, may be negatively affected by heat in summer via decreased conception rates, uterus infection, or reduced intake of feed.

Forestry

While NENA is characteristically arid, forest cover is still present, particularly in Iran and Sudan. Forest degradation and conversion into other land use is reducing the cover. Also, there is a depletion in soil moisture that reduces the productivity of major forest species, increases the fire risk, and changes pest and disease patterns. The impacts are more pronounced in the Near East where declining summer rains will lead to severe water shortages that affect forest growth (FAO, 2016a).

While the largest surface areas covered by forests are in Iran and Sudan, the vulnerable forest resources are not confined solely to these areas. The conifer and mixed relic forests in high mountain ranges, such as Iran, Lebanon, and Syria as well as the southern part of the Arabian Peninsula are highly vulnerable. Already-threatened relic forests, trees and shrub species are also due to be affected. Finally, wetland forests such as the freshwater forest ecosystems in North Africa and the region's coastal forests (such as forests in coastal dune systems along the Mediterranean coast and the mangrove forests on the Red Sea and southern Iranian coastline) are also vulnerable (Tolba, M. and Saab, Najib, 2009).

Fisheries and Aquaculture

Increasing ocean temperatures and ocean acidification (resulting from the ocean's absorption of greenhouse gases) will lead to changes in marine populations, ecosystem structure and biodiversity, and marine species migrations. These effects will then be worsened by the other harmful human activities, including pollution and overfishing. While warming may boost productivity in the Arabian Sea, the catch potential in some parts of the Mediterranean and Red Seas will fall by up to 50 percent (FAO, 2016a). It is important to note that the pressure of fishing activities on fish biodiversity has a greater impact on stocks and ecosystems than climate change. For this reason, fisheries and aquaculture are not examined in depth in this report (RICCAR, 2017).

CLIMATE-IMPACTED FARMING SYSTEM MAPS APPROACH

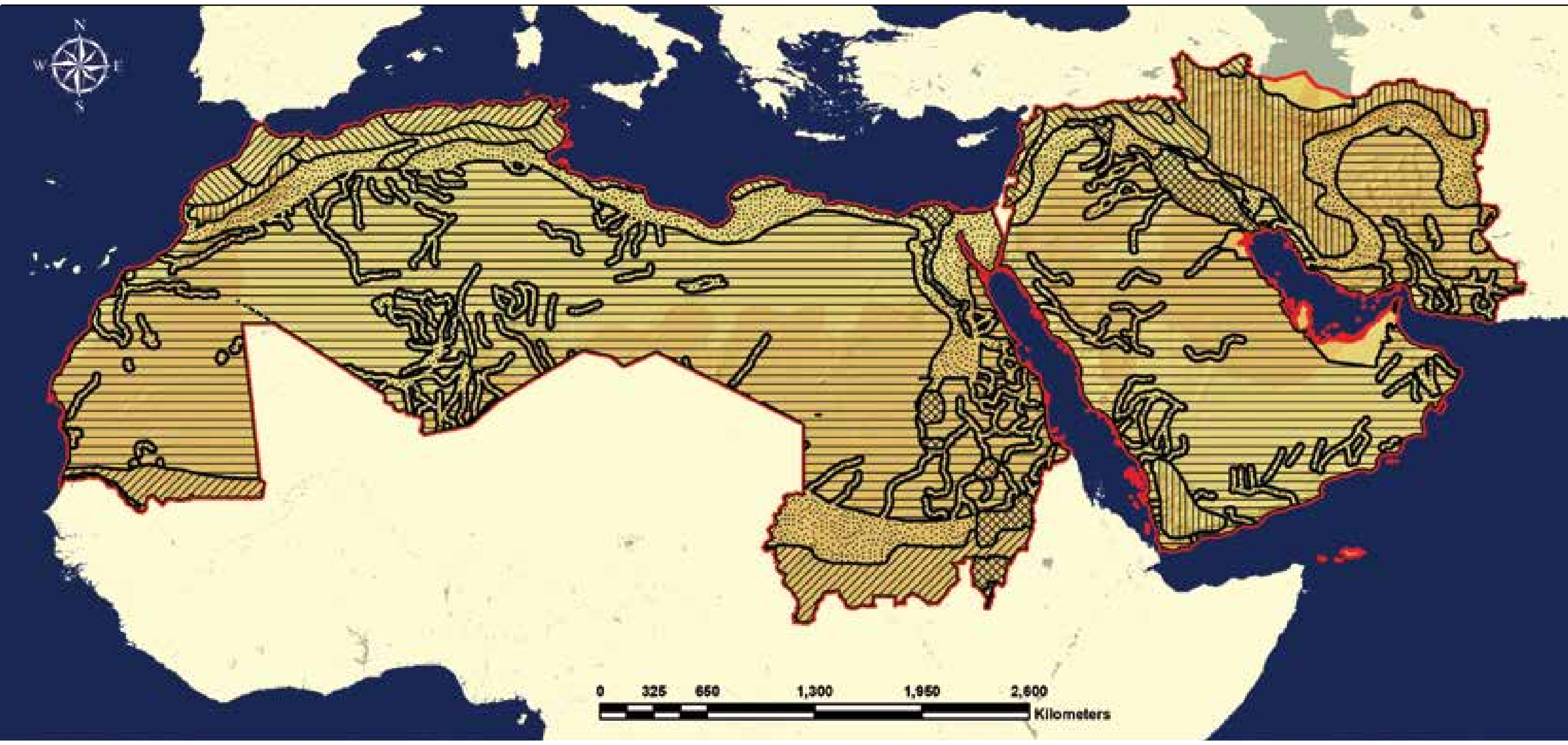
In general, the major climate factors that will affect crop yield stability, pasture productivity and feed quality – and therefore also food and livelihood security for these farmers – are inter-annual and inter-seasonal rainfall variability and temperature extremes. Decreased water supply for irrigation, sea level rise impacts in coastal areas, increased frequency of tropical storms, and rangeland degradation are other climate change induced factors that will impact food availability and therefore food and livelihood security of these farmers (Selvaraju, 2013).

Small-scale farmers are amongst the most vulnerable groups to the impacts of climate change, because they are dependent on agriculture, which is one of the sectors most directly impacted by climate change. These farmers are also characteristically poor and disconnected from the social protection systems that would increase their resilience to climate change. The yields of specific food and cash crops and the productivity of livestock and fisheries used by small-scale farmers will be directly impacted by temperature, CO2 and precipitation changes associated with climate change.

While these general trends exist, it is important to understand the more specific ways in which the various farming systems that cover areas and countries will be affected. Accordingly, all the major farming systems in the region are examined using the CIFS approach that takes data on temperature and precipitation changes and overlays it on data of the major farming systems in the region (Figures 5, 6, 7, 8). The CIFS maps cover changes in temperature and precipitation for the mid-century (2046-2065) for moderate (RCP 4.5) and worst-case (RCP 8.5) scenarios. The analysis below covers the major farming systems of the region.

While important, Bahrain, Kuwait, Oman, Qatar and the United Arab Emirates are not part of major farming systems, and so in-depth analysis was not undertaken for this report. However, it is worth noting that temperature and precipitation changes, and rising sea levels are likely to impact the agriculture in the Arabian Peninsula.

Figure 5. Temperature change in RCP 4.5 (2046–2065) with the farming systems overlaid.



Source: FAO/RNE

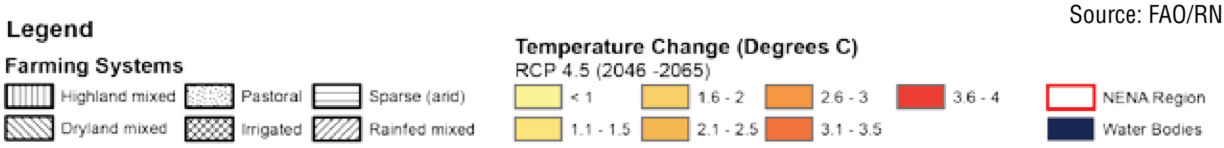
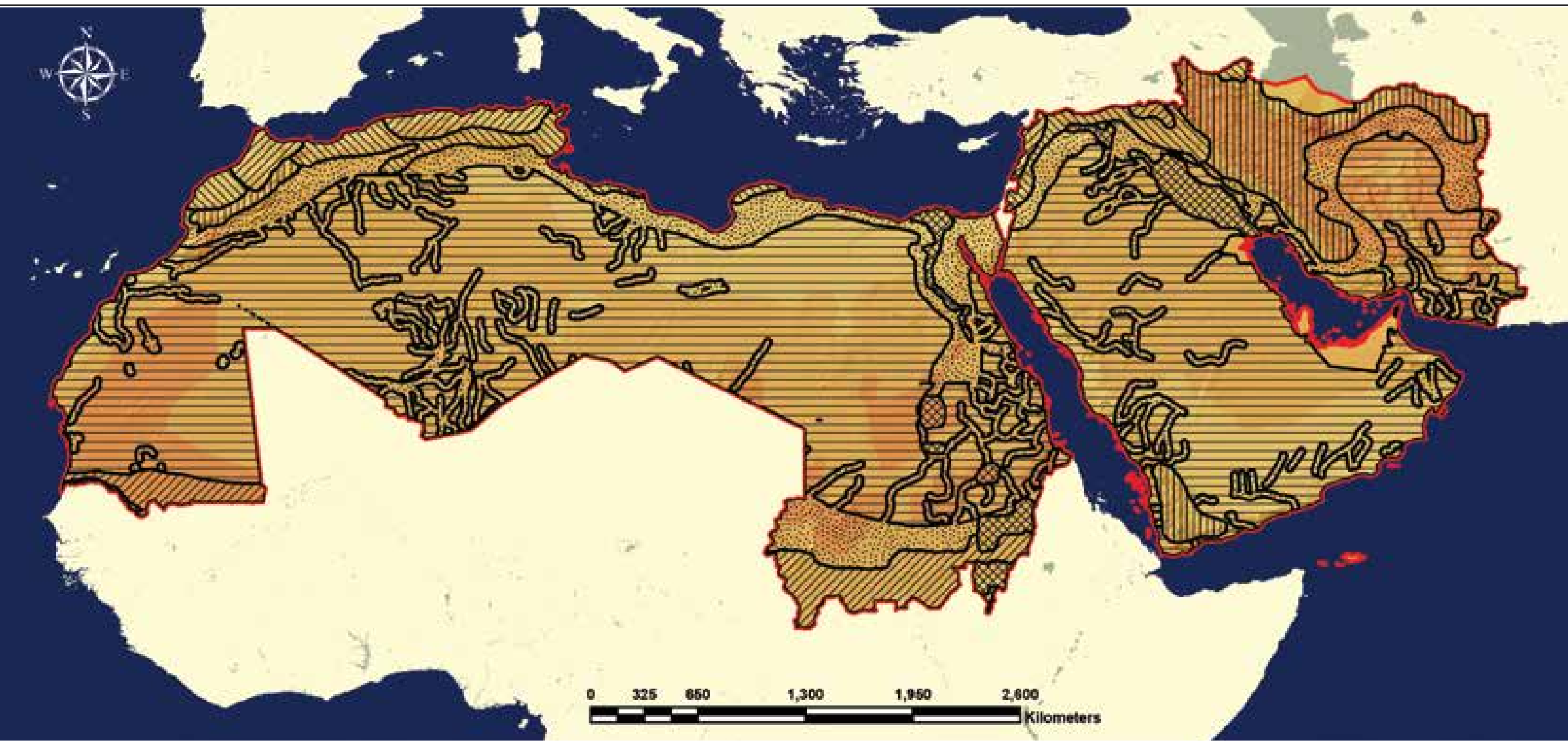


Figure 6. Temperature change in RCP 8.5 (2046–2065) with the farming systems overlaid.



Source: FAO/RNE

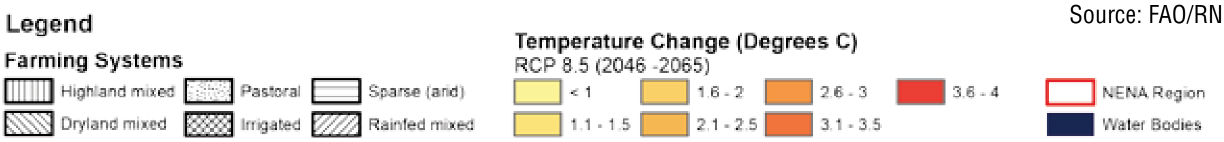


Figure 7. Precipitation change in RCP 4.5 (2046–2065) with the farming systems overlaid.

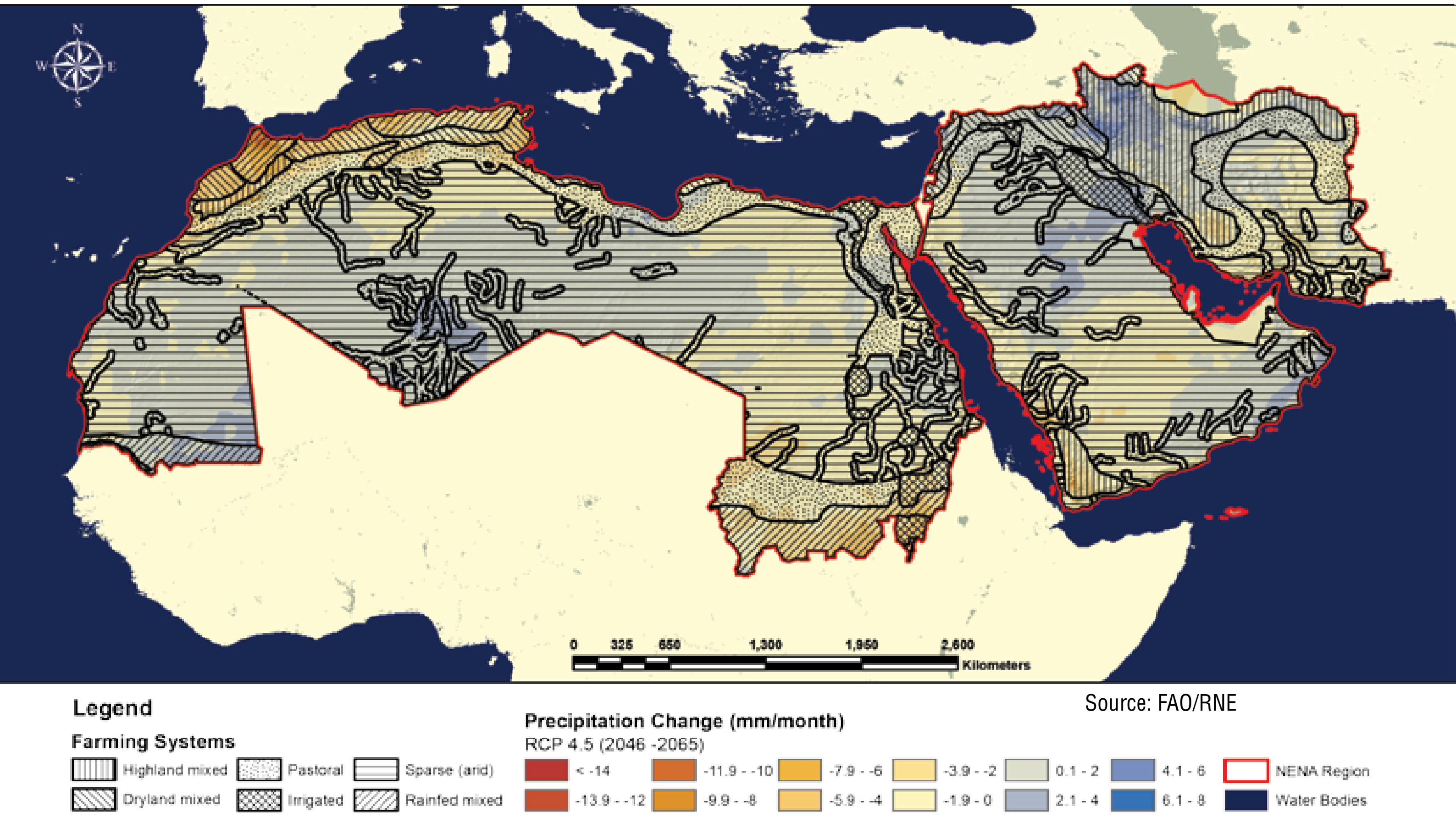
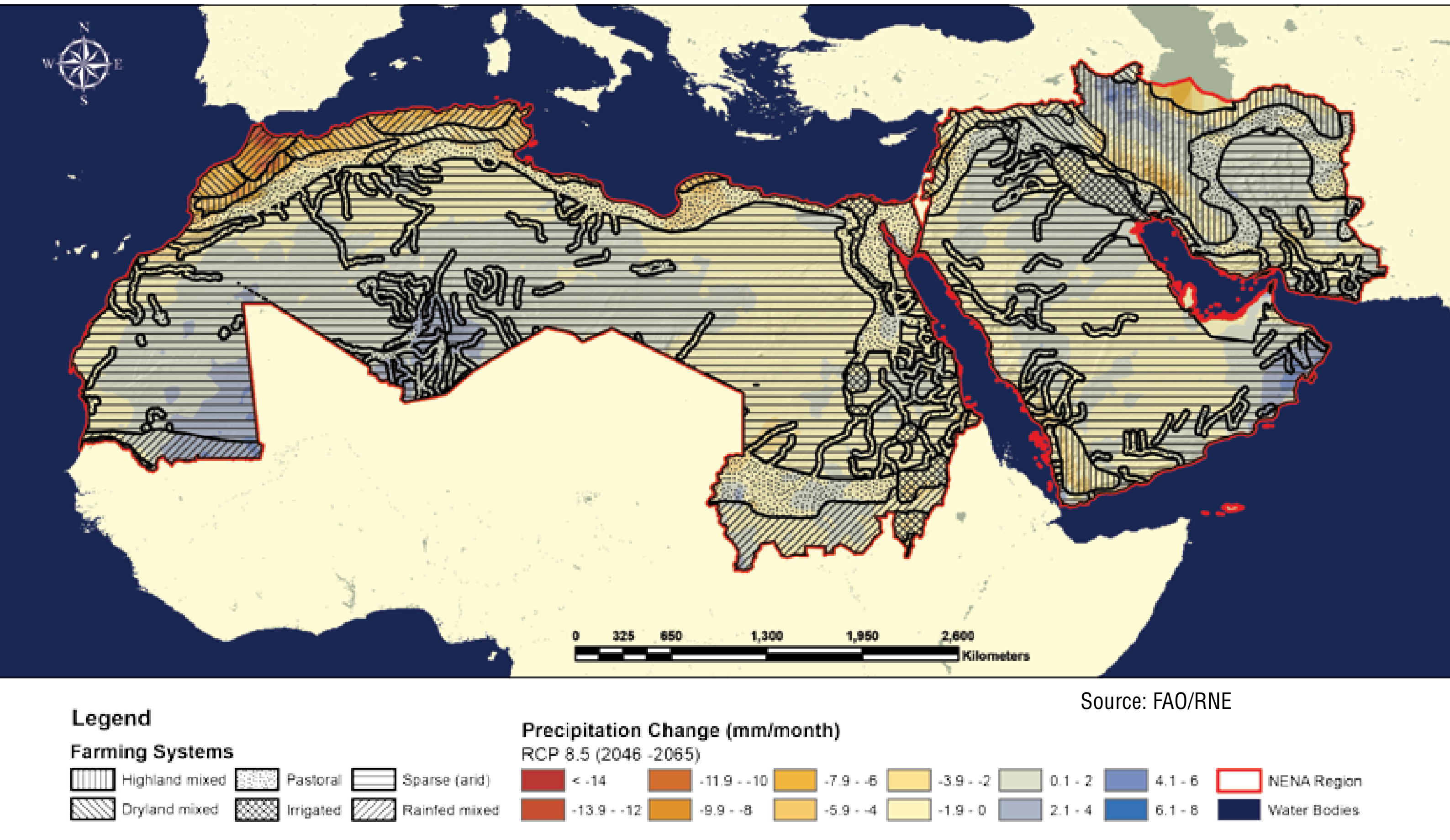


Figure 8. Precipitation change in RCP 8.5 (2046–2065) with the farming systems overlaid.



CIFS 1: Maghreb

Farming systems and livelihoods

Farming systems in the Maghreb sub-region are largely concentrated along the coast except for the rain-fed mixed system along the southern Mauritanian border and the pastoral routes in southern Algeria. Most of the farms are some variation of mixed systems. Rain-fed mixed farming is the most dominant in the sub-region, covering not only southern Mauritania but also northern Morocco, north-eastern Algeria and northern Tunisia. Oases are scattered throughout most of the farming systems of the sub-region.

Mauritania is classified as a least developed country (LDC) with traditional, unindustrialized agricultural practices. Only 0.5 percent of the land is suitable for agriculture, the rest being sparse (arid). The southern corridor and coastal strip have farming systems that are rain-fed mixed with both prominent agricultural and pastoral practices. In the Sahel region along the southern border, sorghum, millet and maize are primarily grown. In the south-west, along the Senegal River, the less arid conditions encourage a greater diversity of crops, including rice, fruits and legumes in addition to sorghum and maize. Farmers in this area are also reliant on the forests for plants, partly for medicinal purposes. The livestock sector provides part or full-time employment to around 60 percent of the country, with sheep and goats being the most common ruminants. Cattle and camels are also kept. Along the coast, fishing activities are dominant. While fishing is a major source of income for the local populations, fishing in this area is largely carried out at the commercial level with a variety of international companies (FAO, 2017f).

Morocco has a variety of mixed farming systems, highland mixed farming is prominent on the north face of the Atlas Mountains, with areas of dryland mixed farming on the southern and north-eastern plains. Rain-fed mixed farming systems occupy the Tingitana Peninsula and the lands behind it leading up to the mountains. In the Atlas Mountains, pastoralism is the most common practice where sheep and goats are mostly kept with a limited number of cattle in some cases. Wheat and barley are grown in these mixed systems. In the rain-fed and highland mixed farming systems, especially closer to the coast, olive, plain and citrus (especially orange) trees are also grown. Berkane oranges are considered high-value crops. Wine grapes, tomatoes and potatoes are also grown (FAO, 2017g).

Compared with other countries in the Maghreb, Algeria has a relatively low coverage of arable land in use for agriculture. Most of the country is arid or semi-arid and affected by desertification and land degradation. The areas that receive more than 400 mm of rain per year are in a narrow strip of land concentrated along the coast. Changes in climate have resulted in a precipitation decline of 30 percent in the past decades. Rain-fed mixed farming systems occupy this land in the north-east and dryland mixed farming systems in the north-west as well as directly south of the rain-fed system, where cotton, figs, esparto grass, and a variety of tree species, including dwarf palm, olive, and fruit such as dates and figs are cultivated. Sheep and cattle are mostly kept in these mixed systems. Also, wheat and barley are grown. Pastoral lands lie along the Atlas Mountain range where sheep and goats are mostly kept (Martin et al., 2014).

In Tunisia, rain-fed mixed farming systems lie on the north western coast and dryland mixed farming systems along the north-eastern. Pastoralism dominants the central band of Tunisia below which the land is sparse (arid). Olive oil and cereal production are the most important agricultural outputs for Tunisia. Cereals – especially wheat and barley – are grown in both rain-fed systems. Olive, citrus and date palm trees are grown primarily along the coastal region in both the rain-fed and dryland mixed farming systems. Other crops are also grown, including tomatoes, peppers, artichokes, melons, onions, potatoes, sugar beets, almonds, apricots and wine grapes. Cereals continue to be cultivated further inland in the dryland mixed system with the southern portion of this system also being used for cattle rearing. Pastoralists in central Tunisia primarily keep sheep, goats and cattle. Small-scale farmers in Tunisia farm can be found to farm for cash or their own consumption. As with many of the Maghreb countries, these farmers are already diversifying their income sources to sustain their livelihoods. The desire to diversify their income is especially true for young farmers, which is resulting in the rising average age of farmers.

While 90 percent of Libya is sparse (arid) desert, small-scale farmers exist in the peninsula around Benghazi and near Tripoli where there are small, coastal dryland mixed farming systems. Wheat and barley are primarily grown in these systems along with olives, dates, potatoes, onions and melons in some cases. The government discouraged the cultivation of tomatoes and citrus in the 1970s due to the large volumes of water they require. Pastoralists keep sheep and goats on the four percent of land that is suitable for grazing (van Steeg and Tibbo, 2012). There is a relatively strong tradition of farmers' cooperatives in the Maghreb. Some of these are official, but there are a variety of informal cooperatives as well, especially female-organised ones (FAO, 2017h).

Climate change trends and impacts

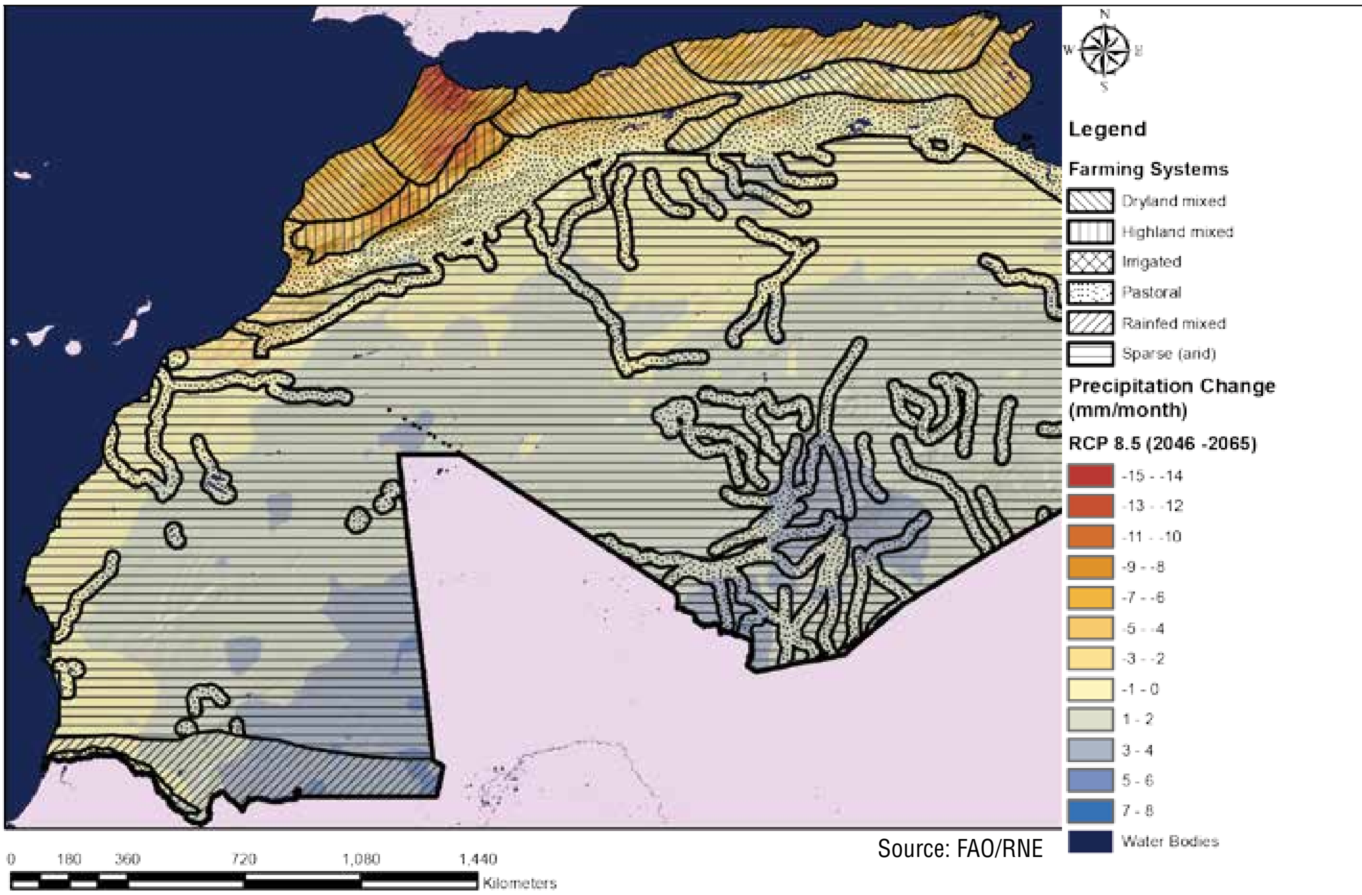
Temperature changes are relatively uniform for the Maghreb countries with the notable exception of Mauritania where the farming systems are due to experience a 2.1–2.5 °C temperature rise by mid-century under a moderate scenario and a 3.1–3.5 °C under a worst-case scenario. The remaining Maghreb farming systems are likely to see a 1.1–1.5 °C temperature rise under a moderate scenario. In a worst-case scenario, the trend diverges where inland areas (2.1–2.5 °C rise) experience higher temperatures than coastal (1.6–2 °C rise) ones (RICCAR, 2017).

Precipitation trends for the sub-region are much more varied (Figure 9). Mauritania houses the only farming systems that observe precipitation increases of up to 6 mm/month in both moderate and worst-case scenarios. The rest of the sub-region is on track for precipitation decreases that will be most pronounced in the Tingitana Peninsula. In a moderate scenario, precipitation is likely to decrease by between 2 and 11 mm/month for the farming systems of Algeria, Morocco and Tunisia. This range goes up to 13 mm/month in a worst-case scenario with many pockets reaching -9 mm/month precipitation trends. The changes in precipitation appear to be more extreme in the mixed farming systems than in the pastoral lands (RICCAR, 2017).

Impacts on Mauritania rain-fed mixed farming system

The relatively extreme rises in temperature will affect all crops. As a summer crop, maize may be unduly impacted whereas sorghum is more heat tolerant. Nevertheless, the changes in temperature (of between 2.1 and 2.5°C in a worst-case scenario) will have implications for the yields of both sorghum and millet unless farmers can effectively adapt planting calendars (FAO et al., 2017). In the south-east, the existent aridity suggests that there are few options for crop diversification and so a greater reliance on sorghum for subsistence may be required by small-scale farmers. In the south-west, the more fertile lands along the Senegal River allow farmers a greater diversity of crops. As temperatures rise, yields in rice, fruits and legumes may decline. Also, the Senegal River has a medium relative vulnerability to sea level rise that could result in the loss of productive agricultural land (IPCC, 2007). Therefore, farmers may need to modify their crop rotation and planting times to offset these potential losses. The greater diversity of crops in the south-west offer farmers in that area greater ability to sustain their on-farm livelihoods and food security since most Mauritanian farmers largely do not grow cash crops. Even so, farmers in both the south-east and south-west keep livestock (mainly sheep and goats) that are amongst the least vulnerable to the impacts of climate change (FAO et al., 2017). This diversity improves the resilience of these farmers. It is worth noting that

Figure 9. Change in annual mean precipitation in the Maghreb under RCP 8.5.



Source: FAO/RNE

Mauritania does not have the same tendency towards off-farm diversification that is ongoing in other countries in the sub-region, which may may pose a problem if climate extremes severely reduce yields (FAO, 2017f).

Impacts on coastal mixed farming systems

In the rain-fed, dryland and highland mixed farming systems of the coastal Maghreb, the main field crops are wheat and barley. These systems are in an area that – under both moderate and worst-case precipitation changes – could be pushed beyond the minimum threshold of water required for the cultivation of wheat. All the coastal mixed farming systems are highly exposed to the impacts of increased heatwave and drought frequency. The Maghreb already has ample experience with such events and their implications. For instance, the 1994/95 drought in Morocco caused gross domestic product (GDP) from agriculture and GDP overall to fall by 45 percent and nearly 8 percent, respectively. Given their lack of access to technological and financial solutions, it was small-scale farmers who bore the brunt of this (Shetty, 2006).

Olives are a major source of income for Maghreb small-scale farmers both domestically and as exports, but yields fluctuate substantially with precipitation, which is projected to reduce more significantly along the coastal plains by between -6 and -9.9 mm/month. Understanding and predicting the changing precipitation patterns in the coastal plains of the Maghreb will become increasingly important for both the subsistence and income of small-scale farmers. The impact will vary within the sub-region as, unlike the rest of the Maghreb and NENA more generally, the Moroccan Highlands will not experience the correlation between precipitation intensity and quantity. Projected temperature rises (around 1.6-2°C in a worst-case scenario) may also result in olive trees having too few days of the cool temperatures that are necessary for germination.

The rain-fed area on the Tingitana Peninsula is expected to suffer the most extreme changes in precipitation in the entire region, in some cases experiencing a drop of around 14 mm/month in RCP 8.5. In fact, wheat in North Africa is one of the natural capital assets most at risk of being stranded (i.e. prematurely losing its value) in the world due to environment or climate-related impacts (Caldecott et al., 2013). It is often suggested that when there is insufficient water to grow wheat, a transition to barley needs to be made. However, as with the rest of the region, barley is grown largely as a fodder crop. Transitioning to using it as a source of food for people would face some barriers, including cultural aversion to barley consumption as well as the lower nutritional value of most barley as compared with wheat. Furthermore, where barely is used as a cash crop, it does not command the price premiums of wheat. Nevertheless, the transition may need to be made given the severity of predictions forecast for these farming systems (RICCAR, 2017).

In these coastal areas, the Sebou and Moulouya Rivers also have a medium relative vulnerability to sea level rise that could result in the loss of productive agricultural land (IPCC, 2007). Rising sea levels could pose more extreme threats in the Sebou River basin that occupies part of the Tingitana Peninsula, which is due to observe the most dramatic temperature and precipitation changes.

The World Development Report (World Bank, 2010) places Morocco among the countries that will suffer the most due to the negative effects of climate change on agricultural yields. In the Moroccan rain-fed and highland mixed farming systems, especially closer to the coast, olive, plain and citrus (especially orange) trees are also grown and their produce sold by small-scale farmers along both shorter and longer value chains, including exports. This source of income is and can continue to build the resilience of these farmers, which will become ever more important as climate change exacerbates the divide between subsistence agriculture in rain-fed areas and more commercial ventures in the irrigated lands. However, methods for optimising water use for these trees will be necessary, especially with the various levels of drying that are most significant in the rain-fed lands, but also notable in dryland and highland lands, ranging largely between reductions in precipitation of between -4 and -13.9 mm/month in a worst-case scenario.

In Tunisia, there is a similar situation with the cultivation of olive, citrus and dates along the coastal region in both the rain-fed and dryland mixed farming systems (FAO, 2017h). This production offers diversification options for farmers, especially for those who can access export markets. However, the yields of these crops are still likely to be negatively impacted by climate change.

The limited arable land and low water availability in Libya suggests that few options exist for maintaining agricultural production as heatwaves and drought become the norm. The dryland mixed farming systems in Libya are close to major Libyan cities, which could offer off-farm livelihood diversification. However, competition for livelihoods will be high in a country that is dealing with internal instability as well as pressures from migration flows.

Compared with its neighbouring countries, Algeria has a smaller and less diversified small-scale agricultural economy. They plant some fruit trees, which could diversify their livelihoods. Potatoes are also commonly grown on the limited irrigated land. Yields of this crop are likely to decline as an indirect result of changes in precipitation and temperature on surface water supplies. Nevertheless, the fact that all these coastal systems are mixed with livestock (mostly sheep, goats and cattle) provides further resilience as incomes are diversified, or the livestock can be sold as assets (FAO et al., 2017).

Impacts on pastoral systems

Pastoralists, whose herd sizes fluctuate largely in correlation with precipitation patterns, are outside the projected areas that will suffer the most severe precipitation declines. Most lands experience a precipitation decrease of up to -1.9 mm/month and in some areas there are increases in RCP 8.5. Inland temperature rises in the pastoral lands are projected to be higher (2.1-2.5°C rise in RCP 8.5) than those experienced on the coast (1.6-2°C in RCP 4.5), which will have implications for herd health and size (FAO et al., 2017). Despite this, the livestock breeds that are traditionally kept in these systems are generally well adapted to harsh conditions. However, the traditional management and mobile grazing strategies that enable pastoralists to adapt to fluctuating grazing resources are impeded because of increasingly restricted access to natural resources, the expansion of croplands, population pressure and existing land tenure policies. Pastoralists will be pushed even further to their limits when having to deal with the increased frequency and intensity of heatwaves and droughts (Akasbi et al., 2012). Therefore, external support is needed to anticipate and build the resilience of pastoralists to adapt to the wide range of shocks (van Steeg and Tibbo, 2012).

Interaction with non-climate stressors

In the context of climate change, the well-established network of cooperatives, especially in Morocco, could enable farmers to pool resources to access technology, markets and information to reduce their vulnerability to the impacts of rising temperatures and reduced precipitation (FAO, 2017g). Livelihood diversification will also need to be considered by many small-scale farmers. Farmers in some countries are already actively doing so. In Tunisia, for example, 58.4 percent of farmers in the south have off-farm jobs, 56 percent in the centre and 31.3 percent in the north of the country. They engage in small commerce, salaried work and artisanal activities to ensure sufficient income. Also, it is mostly young people, and young men especially, that are leaving agriculture. This off-farm work increases reliance on older people and women to manage traditional farming functions (FAO, 2017h).

The Maghreb governments have made concerted efforts over the past decades to increase the development and investment in agriculture. In some ways, this will better prepare small-scale farmers for the impacts of climate change. Tunisia has established a series of banks that provide micro-credit funds and invest in agricultural or fishing projects in areas that are specifically subject to difficult climate conditions (FAO, 2017h). Morocco has developed its "Le Plan Vert Maroc" and – through Crédit Agricole du Maroc – has extended funding to small and medium-scale farmers (FAO, 2017g). Mauritania has also increased its investment in the agricultural sub-sectors over the past decades (FAO, 2017f).

While these are generally positive steps towards the protection of small-scale farmers' livelihoods, other policies such as insurance may need to be adapted in the context of climate change, because the existing insurance either does not cover circumstances made more common by climate change (such as heatwaves, droughts and floods) or they are applied mainly to irrigated land given the emphasis placed on agricultural intensification. Tunisia does, however, offer agricultural insurance against natural disasters and Mauritania does have agricultural insurance to specifically cover individual and cooperative farmers (FAO, 2017f; FAO, 2017g). There is therefore potential to expand the policies and insurance of small-scale farmers in the context of climate change impacts on rain-fed farming systems.

In addition to these policies, there is a need to re-examine the land tenure rights in many areas since insecurity over tenure is leading to short-term, unsustainable land management decisions that will reduce farmers' resilience to climate-induced shocks. Finally, as with most other parts of the NENA region, steady population growth will place increasing pressure on resources and employment opportunities, the latter of which will be especially important to consider as small-scale farmers diversify into off-farm jobs (FAO, 2017a).

Oases and climate change

Oases are an important component of ecosystems in arid areas, often with a rich biodiversity. They are found across the NENA region, which has a strong and rich history of these ecosystems and their contribution to their cultures and economies. This is largely centred on their strong alliance with the date palm tree though other crops (especially olive trees) and livestock are also integral. Oases and the farmers that depend on them are also vulnerable to a host of rapidly changing environmental conditions, amongst which are the impacts of climate change.

These ecosystems have certain inbuilt resilience as their inhabitants are so closely connected with nature and have spent millennia adapting to changing conditions. For instance, communities have traditionally planted strong trees, such as date palms, around the perimeter of oases to minimize the impacts of sand storms and desert encroachment that is a perennial issue. However, some of the main challenges to ensuring the sustainable adaptive management of oases in the NENA region are the lack of information available about them and awareness amongst policymakers about the economic and agro-ecological importance of these ecosystems. Given their geographic isolation, there are limited options for oases inhabitants to diversify their livelihoods without migrating.

CIFS 2: Mashreq

Farming systems and livelihoods

There is a diversity of farming systems in the Mashreq, including rain-fed mixed, dryland There is a diversity of farming systems in the Mashreq, including rain-fed mixed, dryland mixed, pastoral and irrigated systems. The rain-fed mixed farming systems dominate Lebanon, northwest Syria and the northernmost parts of the Tigris River headlands. Dryland mixed farming systems run along western Syria and the headlands of the Euphrates and Tigris Rivers (i.e. northern Syria and northern Iraq). Pastoral lands cut across Syria from south-west to north-east and extend into north-western Iraq. The land along the rest of the Euphrates and Tigris Rivers is irrigated.

Small-scale farmers in the rain-fed mixed system in Lebanon, northwest Syria and the West Bank and the Gaza Strip sell their products along short, local value chains. Around 37 percent of these farmers in Lebanon also use part of their produce for subsistence. They are mostly dependent on permanent crops, which constitute 78 percent of their crop production. Of these permanent crops, olive trees are the dominant crop, representing 43.6 percent of production, followed by pome fruits, viticulture and citrus. Many of these farmers also keep livestock with around 54 percent keeping cattle, 40 percent keeping pigs, 37 percent keeping goats, and 35 percent keeping sheep (FAO, 2017b).

The dryland mixed system in the headlands of the Euphrates and Tigris is used primarily for grazing livestock (mostly sheep and goats), as well as cereal and pulse production. The cereal and pulse production are fed by irrigation closer to the river, but rain-fed elsewhere. Of these, wheat, barley, chickpeas and lentils are the major crops. These crops are also grown in the pocket of rain-fed mixed farming systems in the north of Iraq (World Bank and FAO, 2012).

Irrigated farming systems dominate the Fertile Crescent between the Euphrates and Tigris rivers, and continue when the two rivers merge to form the Shatt Al Arab / Arvand Rud area. The major crops on these irrigated lands are rice, maize and sunflower. Rice is the second most important staple crop after wheat. Livestock – especially goats and sheep – are also kept by most farmers here. Maize is a relatively new crop in this area. Both rice and maize suffered losses due to a lack of fertilisers and pesticides following sanctions imposed upon Iraq. Small-scale farmers also engage in fishing activities in the Fertile Crescent, especially of shad, mullet and catfish. Fishing is used either for subsistence or sold along short value chains (World Bank and FAO, 2012).

Pastoral farming systems exist, especially in northern Iraq between the dryland mixed and irrigation farming systems, as well as across the central belt of Syria. Although the mapping of potential impact on livestock for these pastoral areas showed limited impact under both RCP 4.5 and RCP 8.5 for mid-century, the expected increase in temperature and decrease in precipitation will have an adverse impact on livestock unless necessary adaptation measures are taken into consideration.

In addition to having diversified agricultural livelihoods, most small-scale farmers in Lebanon engage in off-farm activities to build their resilience to shocks and to ensure sufficient resources for their families. In fact, around two-thirds of small-scale farmers in Lebanon are engaged in other sectors (FAO, 2017b). Less research is available for small-scale farmers in Syria and Iraq than for Lebanon. Nevertheless, it is assumed that–where possible–these farmers also diversify their livelihoods. For both Iraq and Syria this will become necessary because of the loss and damage caused to the agricultural sector due to conflicts in both countries (FAO, 2017c

Climate change trends and impacts

The temperature trends for the Mashreq region are more nuanced than those for precipitation. The region overall will be impacted by the long-term warming trend already observed throughout the eastern Mediterranean that will add to the drawdown of soil moisture which, as previously discussed, exacerbates the drying trend for this area as it suppresses surface cooling (Kelley et al., 2015). By the mid-century, changes in temperatures of more than 1.6°C are projected for north and north-eastern Syria, southern Syria, eastern Jordan and the land along the Euphrates and Tigris Rivers in a moderate scenario. The entire region is projected to exceed this threshold under a worst-case scenario, with north-eastern Syria, Iraq and parts of Jordan marking temperature changes of 2.6–3°C (RICCAR, 2017).

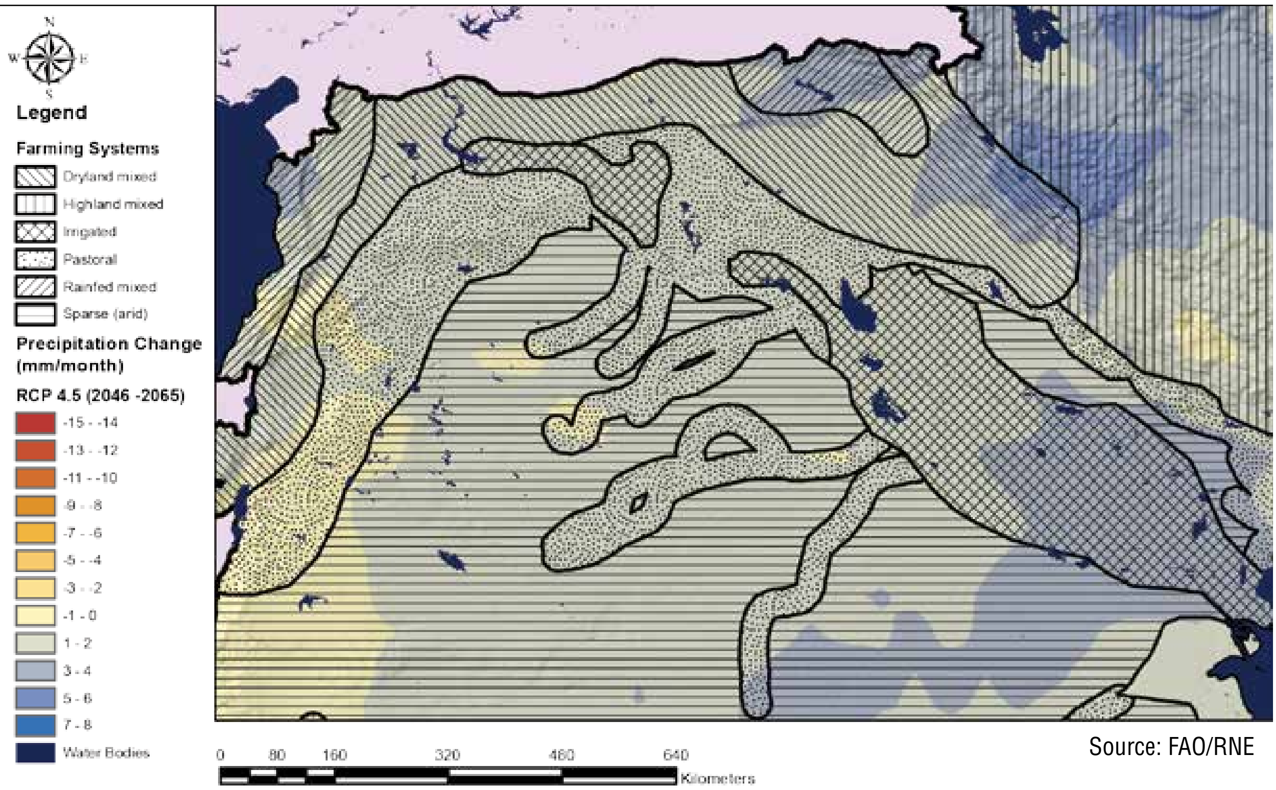
The area is projected to observe a long-term drying trend that is already underway, which relates to the rising mean sea-level pressure in the eastern Mediterranean (Kelley et al., 2015). The majority of the area observes a slight increase in precipitation (0.1–2 mm/month) by mid-century in a moderate scenario (Figure 10). Under a worst-case scenario, there is a reduction of -1.9–0 mm/month in northern and western Syria by mid-century. Northern Lebanon and parts of coastal Syria experience even more extreme changes of between -2 and -7.9 mm/month decreases (Figure 11) (RICCAR, 2017).

Impacts on rain-fed mixed farming systems

Rain-fed farming systems are particularly exposed to the impacts of climate change because both temperature and precipitation directly influence them. In the Lebanese, Palestinian and Syrian rain-fed farming systems, the main crop – olives – are especially likely to be impacted because of the strong positive correlation between fluctuations in rainfall and olive yields. This is especially the case in central Lebanon and southern West Bank where precipitation is expected to drop by up to -7.9 mm/month in RCP 8.5. Olive yields are projected to decrease 65–90 percent under RCP 4.5 and by more than 90 percent RCP 8.5 by the end of the century throughout the region (FAO et al., 2017). Olive yields will also be impacted by the increase in temperatures (around 1.6-2°C in RCP 8.5) since olive trees require at least two months of cold weather to produce flowers and fruit. Since olives are used as a key source of income for these farmers, the impact on their livelihoods will be significant. This risk can be reduced through supplemental (especially drip) irrigation that will reduce reliance on rainwater, but in the context of climate change, this may also be challenging as there will be an increased demand overall for irrigation (FAO, 2017b). In the West Bank and the Gaza Strip, issues of secure access to land and water are also a challenge. The other crops grown in this area, especially those with large water requirements such as bananas, will also be impacted. For several crops, farmers will need to consider changing their planting times in accordance with the changes in precipitation, which will be more notably reduced in the central Beqaa region of Lebanon (RICCAR, 2017).

Fortunately, small-scale farmers are operating integrated crop-livestock systems that will strengthen their resilience to the impacts of climate change. Lebanese small-scale farmers, in particular, have notably more diversified incomes (Elbehri and Sadiddin, 2016). It is important to note that the most commonly kept ruminant – cattle – is also the most vulnerable to the impacts of climate change in this zone (FAO et al., 2017). However, farmers have a mix of cattle, goats and sheep, which ensures a diversified income base. Also, the fact that around two-thirds of Lebanese farmers are already diversifying into non-agricultural livelihoods further

Figure 10. Change in annual mean precipitation in the Mashreq under RCP 4.5.



Source: FAO/RNE

prepares them for the impacts of climate change. As with other potentially impacted farming systems, the diversification of livelihoods will change gender dynamics on-farm with women playing a larger role (World Bank, 2016).

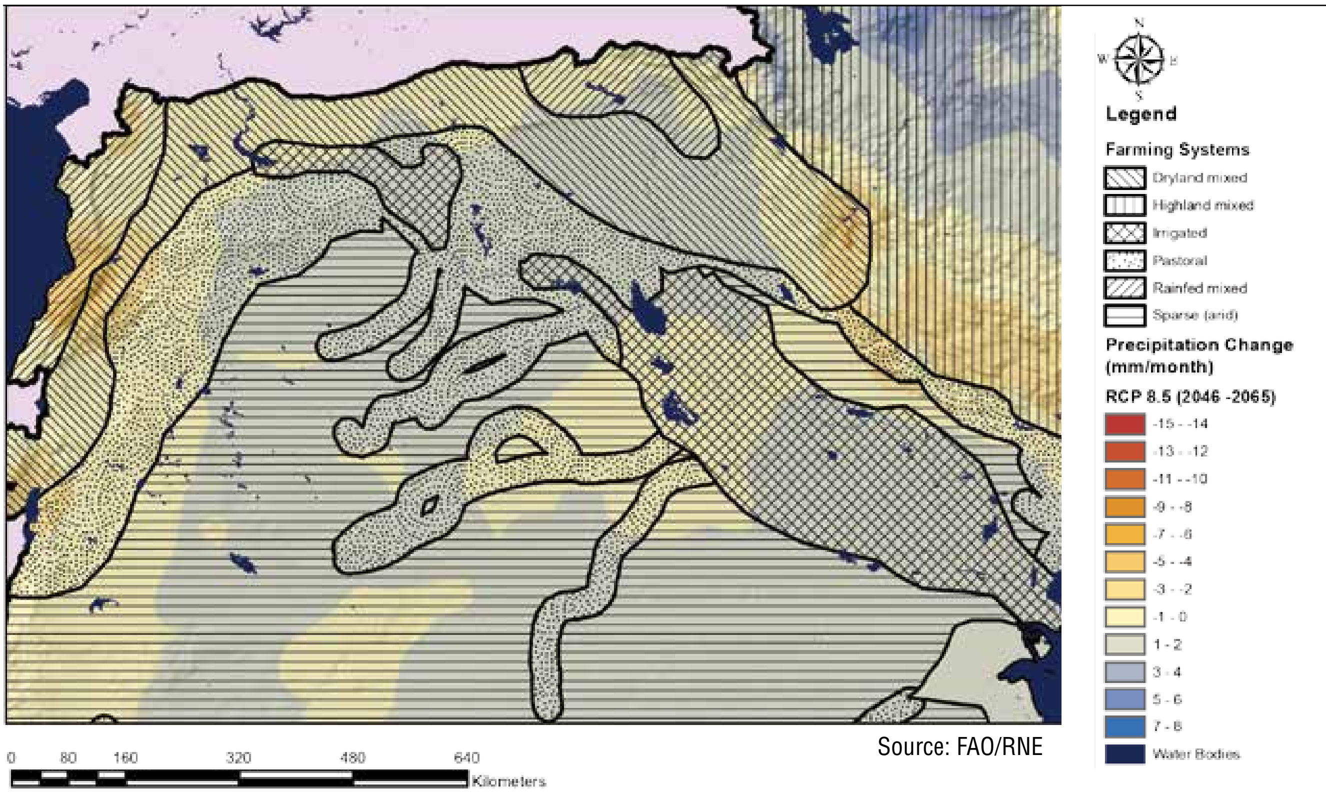
Impacts on dryland mixed farming systems

The dryland mixed farming systems that exist in north-western Jordan and the headlands of the Euphrates and Tigris will not only experience an increased demand for irrigation observed in the rain-fed mixed farming systems; they also run the risk of transforming into rangeland due to an overall decrease in precipitation of up to -1.9 mm/month in RCP 8.5. These risks are particularly

challenging for small-scale farmers because the transition from dryland mixed farming systems to more arid rangelands will push these farmers even more to the natural resource margins than many already are (Wenger, 2012).

In Jordan, where wheat and barley are grown in close proximity, the warming (mostly 1.6-2°C in RCP 8.5) and drying (mostly up to -1.9 mm/month in RCP 8.5) trend may necessitate a greater emphasis on barley production with its importance for local community food and as feed for livestock. The reduction in precipitation is especially accute around the Dead Sea. Increased

Figure 11. Change in annual mean precipitation in the Mashreq under RCP 8.5.



Source: FAO/RNE

reliance solely on barley is not sustainable for the food supply or livelihoods due to its relatively low nutritional value and its perceived use primarily for animals. Farmers also grow cucumbers, tomatoes, eggplants, melons, bananas and citrus. Diversification of crops in this manner is important for managing the impacts of climate change, such as the heatwaves that are likely to become more commonplace throughout the Mashreq (Lelieveld et al., 2016).

Similarly, in Iraq and Syria, the major crop in this farming system is wheat which is also the staple crop for small-scale farmers. Syria saw overall average annual yields of wheat drop from 3.4 million tonnes pre-conflict to just 1.8 million tonnes in 2017 (FAO and WFP, 2017). Iraq recorded around 4.03 million tonnes of wheat production in 2017 (Index Mundi, 2018). Wheat production on these lands is expected to decline by 25–35 percent by the mid-century under RCP 4.5, which will severely jeopardise the livelihoods of these farmers. This trend has already been observed because of the droughts that characterised Syria particularly from 2006 to 2011.

For Syria, the north-eastern "breadbasket" region produces over two-thirds of the country's crop yields (Kelley et al., 2015). Some limited parts of this region will experience a minor precipitation rise (0.1-2 mm/month in RCP 8.5) and the entire region is expected to experience higher temperature rises than the rest of the country, around 2.1-2.5°C in RCP 8.5. The effect of these changes in temperature and precipitation are not unheard of in this part of Syria. During the 2007–2010 drought, Syria saw the driest winter on observational records in 2008 in which small-scale farmers saw zero or near-zero production and nearly all livestock herds were lost. While Syria is accustomed to multi-year droughts, the effects of this drought and potential future droughts are much more pronounced because of an increased water demand, a reduced buffer for water availability resulting from reduced groundwater, and the lack of recovery time from previous droughts (Kelley et al., 2015). Some modelled and observational analyses suggest that the devastating nature of this drought would not have been possible without human-generated greenhouse gas emissions. Further, the CO2 emissions driving climate change make

Considering natural resources in conflict and post-conflict peacebuilding

The consideration of natural resources, how they have, and how they will be affected by climate change are essential for a sustained peacebuilding process. Often, this is challenging for policymakers to prioritize given other competing considerations in the peacebuilding process. Nevertheless, experience has demonstrated that environmental assessments influence post-conflict priorities. This is partly because disputes for natural resources–which are changing and becoming more constrained because of climate change–can be a contributing cause of conflict, and therefore, consideration of these natural resources in the context of climate change is important. Rapid and strategic assessments that identify the main issues to inform policy priorities are better than comprehensive research that misses the opportunity to influence early decision-making. Such assessments can be followed with the remediation of environmental hot spots, the restoration of damaged or degraded resources to support livelihoods, and a reconstruction process that minimizes adverse socio-environmental impacts. Land tenure is frequently a key barrier to meaningful restoration and management of natural resources.

the most severe three-year droughts two to three times more likely (Kelley et al., 2015). The consequent loss of agricultural livelihoods contributed to many families leaving the area, most of whom migrated to peri urban Syria. The socio-economic implications of this trend were then compounded by the influx of Iraqi refugees, which together, made up 20 percent of Syria's urban population. Given that the corresponding area in Iraq is somewhat less dependent on agriculture, the impacts on livelihoods will be somewhat reduced as compared with Syria.

In addition to the production of wheat, barley is also commonly grown primarily as fodder for the livestock in these systems. While projections vary, this rain-fed crop is expected to experience notable declines in yield. In addition to the impacts of climate change, the conflict in Syria has taken a heavy toll on such annual crops, with Ar-Raqqa, Deir ez-Zor and Al Hassakeh provinces surrounding the Euphrates River all suffering severe losses. Some areas experienced losses of over USD 550 million (FAO, 2017c). Wheat and barley production continues as the Euphrates River extends into Iraq. This area is the breadbasket of the country and will likely suffer the same impact to the food security of small-scale farmers as seen in Syria, which will reduce the ability of farmers to maintain an integrated crop-livestock system. As temperature and precipitation patterns change, farmers may need to rely on barley, a drought-tolerant crop, despite reduced overall yield (Steduto et al., 2012).

As with the rain-fed mixed farming systems, small-scale farmers in the drylands also keep livestock. Mountain goats are the major group of ruminants grazing in the mountains, with Shami goats further south. Normally they graze during the day and return to village enclosures at night where they are fed some concentrates. The average herd size (pre-conflict in Syria) was between 75 and 125. However, these numbers have severely declined post-conflict, with 60% of households reporting that the main reason for the decrease in animal ownership was the sale of animals as a coping strategy. The greatest damage and loss of livestock is in the area around the Euphrates, with Ar-Raqqa province recording USD 300–600 million damage and loss due to livestock and Deir ez-Zor recording over USD 600 million (FAO, 2017c). Despite these impacts, maintaining these herds will build the resilience of these small-scale farmers since they have fewer opportunities for diversification into other agricultural and non-agricultural livelihoods largely because of the conflicts and post-conflict impacts in these two countries.

Impacts on Fertile Crescent irrigated farming systems

Small-scale farmers in these systems rely primarily on rice for subsistence as well as selling this crop along short value-chains. There are no pertinent data on the impact of climate change on rice yields for the region with other regions showing both increased and decreased yields with higher CO_2 emissions (Kang et al., 2009). Even so, this crop is highly water-intensive. Changing temperature and precipitation patterns – alongside the constant riparian challenges associated with both the Euphrates and Tigris Rivers – will alter water availability to produce rice. Almost all areas will likely experience a 2.1-2.5°C rise. In a moderate scenario, there will be an increase in precipitation, especially downstream in the Shatt Al Arab / Arvand

Rud area (of 4.1-6 mm/month). However, this increase in precipitation is associated with increased precipitation intensity, which could result in floods and the associated soil erosion and crop loss. Since this area also has a moderate relative vulnerability to sea level rise, this could exacerbate crop yield losses (IPCC, 2007). Further upstream, a drying of up to -1.9 mm/month in the heart of the Fertile Crescent is projected under a worst-case scenario (RICCAR, 2017). Small-scale farmers may need to diversify from this staple crop under variable and drying conditions. Fortunately, the drying effect will be observed closer to Baghdad, which may suggest that diversification options into off-farm livelihoods could be a viable option.

The declines anticipated for maize yields are not very great, in the range of zero to four percent by the mid-century in the moderate and worst-case scenario, respectively, which suggests that livestock which partly rely on this crop for fodder will not suffer greatly as a result (FAO et al., 2017). Nevertheless, goats and sheep owned by small-scale farmers in this irrigated farming system are still expected to feel the impacts of changes in temperature and precipitation forecast for the Fertile Crescent.

While there are a large number of small-scale farmers in this farming system and they are exposed to the impacts that climate change will have on their livelihoods, they have more diversified incomes than other regions, which strengthens their resilience. It is in this irrigated land that the majority of Iraq's vegetable, sunflower and rice production takes place. In addition to which, marsh fishing is also a cornerstone of the economy (Mohamed and Al-Noor, 2008).

Overall, small-scale farmers in this farming system will need to be most conscious of how to sustainably manage their irrigation patterns to maintain fruitful agricultural livelihoods. Continued diversification into non-agricultural labour will also be necessary. Though, as Iraq is still largely in a post-conflict state, consistent off-farm work may be challenging.

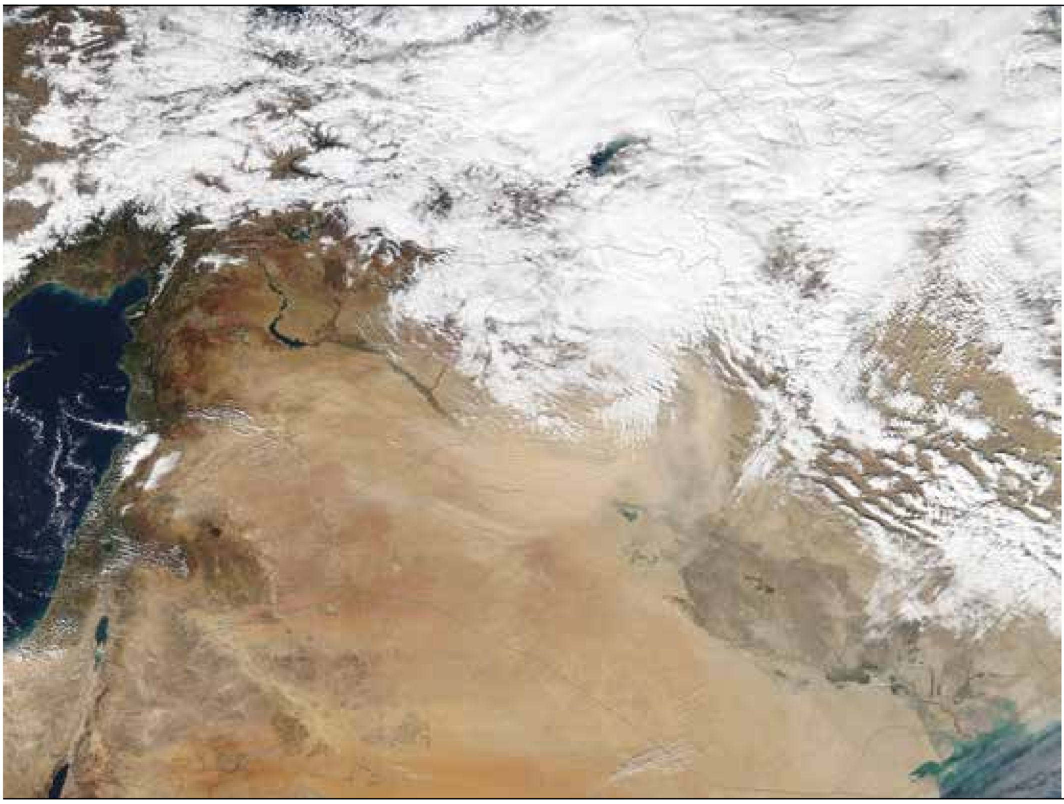
Interaction with non-climate stressors

The Mashreq area deals with a series of factors that will be made more complex in the context of climate change. They largely revolve around a need for improved natural resource management. Given its dependence on agriculture, Syria has been adversely affected by policies that focused on increasing agricultural production at the expense of sustainable resource management. These policies have resulted in an overexploitation of land and water resources through the proliferation of irrigation projects, quota systems and subsidies for diesel fuel (Kelley et al., 2015).

The impact of climate change in Turkey, where the headwaters of the Euphrates and Tigris Rivers lie, will have direct consequences on the amount of water received in Iraq and Syria that can be used for agriculture. Also, there are the transboundary shared water governance issues that impact Iraq and Syria most notably. The river damming associated with this–as well as general poor land management that results in erosion and desertification–is driving a trend of sand and dust storms across the Mashreq (Figure 12) (Hamidi et al., 2013). Climate change is likely to exacerbate these storms, which have the propensity to impact agricultural productivity

(UNEP et al., 2016; Zhang et al., 2003).

Figure 12. Dust plumes arising from points in Syria and north-west Iraq blow south-east in 2011



Source: NASA, 2011

CIFS 3: Nile Valley (Egypt and Sudan)

Farming systems and livelihoods

The farming systems in Sudan are largely divided into horizontal belts with pockets of irrigated and pastoral farming systems further north. From south to north, there are cereal-root crop mixed, irrigated, agro-pastoral, pastoral and sparse (arid) farming systems. The Nile Valley is effectively entirely irrigated with pastoral farming systems lying directly outside of this irrigated land on both the east and west banks of the river (FAO, 2017d).

Sudan's cereal-root crop mixed system and agro-pastoral system, which are in the south-western part of the country, mostly grow millet (dukhon) on around 60 to 70 percent of the cultivated areas by small-scale farmers. The remaining land is used to cultivate groundnuts, sesame, cowpeas (lubia) and roselle (karkadeh) (FAO, 2017d).

These agro-pastoral and cereal-root crops extend into the south-east of Sudan. Closer to the Nile River, irrigated agriculture is also present, but this occurs only in pockets as the Nile River passes through the sparse (arid) farming system in the northern part of the country. The crops grown on these lands are primarily sorghum, which is the staple of the area, as well as sesame and groundnuts. Vegetables are also grown for local consumption, such as broad bean, fennel, potato and onion. Most of the small-scale farmers in both the south-west and south-east of Sudan also keep some animals for food, milk, fieldwork or transport, mostly goats or sheep. In fact, more than 50 percent of annual household income comes from livestock in agro-pastoral systems (FAO, 2017d).

Further north, there is a belt of pastoral land, which extends along part of the Nile River and its tributaries in northern Sudan. Pastoral livelihoods in this area can be either nomadic, semi-nomadic (transhumance) or agro-pastoral. Nomadism is practised by a small group who are either camel or cattle herders. Nomads are primarily camel pastoralists (abbala) who will often also keep small ruminants such as goats or sheep, which are looked after by women and boys around the camp while the men look after the camels. Camels are used for their meat or, more often, for their milk. Small ruminants are used as a livelihood diversification strategy (FAO, 2017d).

Semi-nomads–those with who only migrate seasonally and have a home base–are primarily cattle herders. Cattle herders (baggara) are mainly located in high rainfall savannah as cattle are more dependent on rainfall than camels. Cattle are used mostly for their meat, which supplies 70 percent of the Sudanese red meat market. They are also used for their milk products and milk by-products. For pastoralists, milk is the sole domain of women. Cattle herders will often also cultivate some crops for subsistence (FAO, 2017d).

The farming system along the banks of the Nile River in Egypt is irrigated, and 94.8 percent of all small-scale farmers in Egypt depend on the Nile water for irrigation. Cereals, legumes, sugar crops, oilseeds and forages are cultivated by small-scale farmers for their own consumption with the surplus being sold at the nearest market. Rice, wheat and maize are the major cereal crops cultivated, occupying most of the irrigated land. Unlike rice and wheat, maize is used largely for livestock and poultry feed. Sugar cane and sugar beet are grown along the Nile River in Upper (southern) Egypt as well as the Nile Delta. Broad beans and soybeans are also cultivated (FAO, 2017e).

Where these field crops are not grown, horticultural crops (fruits and vegetables) are grown instead and used as cash crops. These include Egyptian clover, berseem, oranges, grapes, stone fruits and pome fruits. Clover and berseem are commonly cultivated in the Nile Delta. Regarding fruit, oranges are the most important, representing 85 percent of total citrus production. For vegetables, tomatoes are the most important even though they represent only around three percent of Egypt's total planted area. Potatoes are the second most important vegetable after tomatoes. Medium and large farms focus on the cultivation of horticultural crops instead of field crops, whereas the small-scale farmers focus more on field crops. Furthermore, traditional farming systems such as those employed by small-scale farmers are typically mixed and integrated crop-livestock systems. In 2010, 68.5 percent of small-scale farmers had large ruminants (i.e. cows and/or buffaloes), and 47.3 had small ruminants (i.e. goats and/or sheep) (FAO, 2017e).

Most of these small-scale farmers supplement their livelihoods with off-farm income as the produce from their crops and livestock is insufficient to sustain them. They diversify into a variety of primarily rural activities with a smaller portion obtaining part of their livelihood in urban areas (FAO, 2017e).

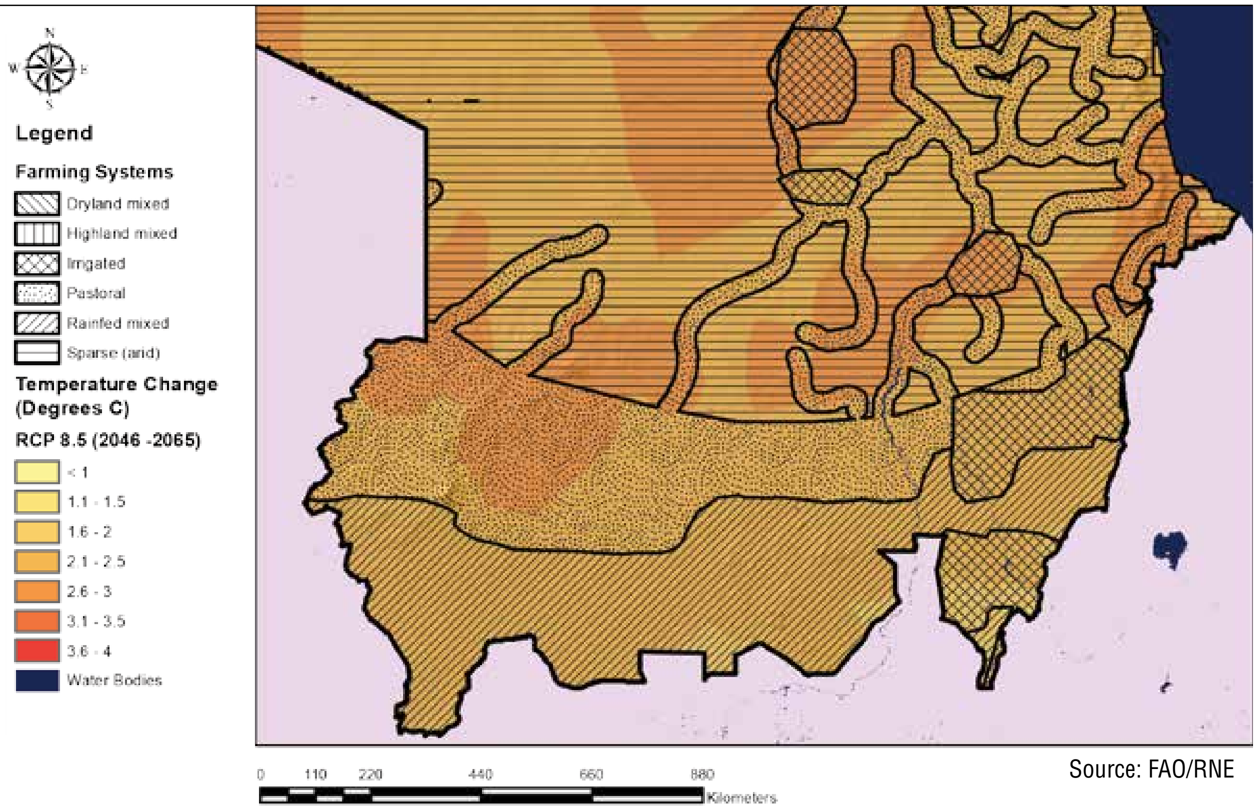
Climate change trends and impacts

As with the rest of the region, there is consensus of a general rise in temperatures over this century. The Nile Valley in Egypt and Sudan leading north to the Nile Delta are projected to experience more than a 1.6 °C temperature rise by the mid-century in a moderate scenario, whereas the entire Nile River will experience this minimum in a worst-case scenario (Figure 13). Even though the Nile Delta area is expected to experience less extreme, but still notable temperature changes, it will have to contend with the impacts of sea level rise as well. Pockets

along the Nile River and pastoral lands in Sudan will observe more pronounced temperature increases in the RCP 8.5 scenario.

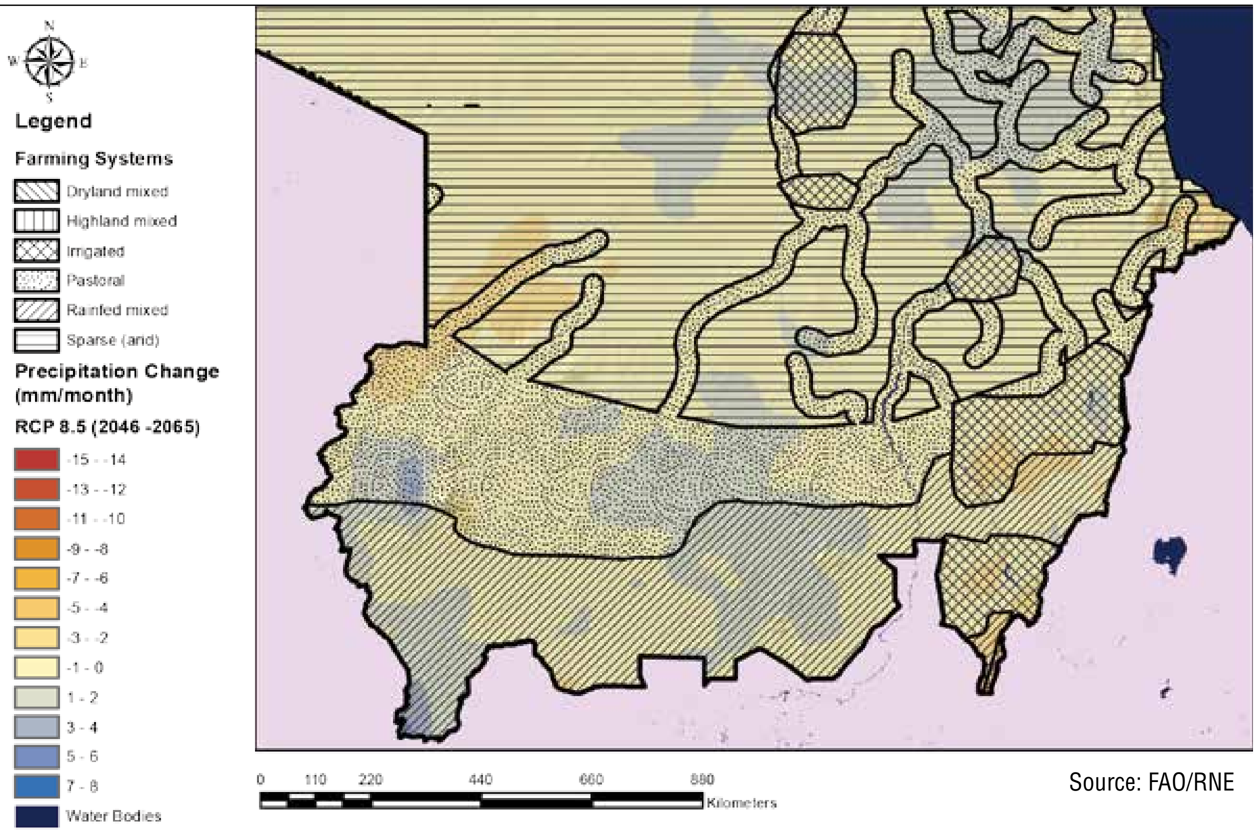
Under both scenarios, the Nile Valley and southern Sudan both experience a decrease in precipitation. Along the Nile, this is primarily a decrease up to 1.9 mm/month with a few pockets, notably in the Nile Delta, that experience a minor increase of 0.1–2 mm/month. Given that the agriculture along the Nile Valley is largely dependent on irrigation, this trend may not be of direct relevance to the small-scale farmers in this area. Nevertheless, the variability in precipitation at the sources of both the Blue and White Nile will influence the amount of water available downstream for irrigation. The decrease in precipitation is more pertinent for the rain-fed areas of Sudan, and it is in these areas that more dramatic decreases in precipitation of between -2 and -7.9 mm/month occur (Figure 14) (RICCAR, 2017).

Figure 13. Change in annual mean temperature in Sudan under RCP 8.5.



Source: FAO/RNE

Figure 14. Change in annual mean precipitation in Sudan under RCP 8.5.



Source: FAO/RNE

Impacts on Sudanese cereal-root crop mixed system and agro-pastoral systems

Small-scale farmers are by far the largest category of the agricultural sector workforce in the country. They farm largely for their own consumption, with any excess being sold to the market. Many of these farmers, however, already cannot survive based solely on subsistence and cash crops and are already engaged as seasonable agricultural workers on large-scale semi-mechanised farms and in urban areas to supplement their income.

Small-scale farmers in Sudan's cereal-root crop mixed system and agro-pastoral system depend largely on millet and sorghum. Millet is grown largely in rain-fed areas which are amongst the most vulnerable because of increased aridity, while unpredictable rainfall and the risk of drought may necessitate delayed planting, with negative impacts on yields (Wenger, 2012). Some data shows a more pronounced increase in temperature during summer months, with annual averages still around 2.1-2.5°C higher in RCP 8.5. Thus, a summer crop like millet may be negatively impacted. Crops may not mature, fail altogether or produce less yields if planting is delayed by more than a few weeks. A trend that could be compounded by heatwaves that have become more frequent over the past decades as well as the projected increase in tropical nights, hot days and very hot days (Lelieveld et al., 2016). Unpredictable rainfall and the declines in precipitation that are projected to be above the regional average (some parts of southern Sudan reach -7.9 mm/month declines) in this area may also lead to drought during the growing season, resulting in yield losses. Therefore, expected changes may not only affect the yield of one crop but might affect the whole farming system including choice of different crops or different varieties of the same crop, which will impact the food security of these farmers.

Sorghum is the staple crop in the south-eastern states (River Nile, Khartoum, Al Jazirah, White Nile, Sennar and Blue Nile) where is cultivated by both irrigated and rain-fed semi-mechanised systems. There is some divergence amongst projections of the impacts of climate change trends on this crop. However, whether increasing or decreasing, for irrigated sorghum the change from the baseline levels is not very great at around +2 to -6 percent for the least vulnerable areas and -4 to -13 percent for the most vulnerable groups. The comparatively limited impact of climate change on sorghum in irrigated land along the Nile River is beneficial given sorghum's role as a subsistence crop for the already-poor small-scale farmers in these states (FAO et al., 2017). Sorghum is also generally considered drought resistant, which makes it ideal for food security in a changing climate. Drought resistant crops are especially important since the marked changes in temperature and precipitation will place an increased demand on irrigation (Wenger, 2012). Increased adoption of sorghum, with its comparatively short growing period, therefore, could lessen water demand for irrigation (Steduto et al., 2012).

In addition to these two staple crops in the irrigated lands along Nile Valley, key vegetables like potatoes and tomatoes demonstrate potential yield losses, which could have a major impact on the food security of these farmers. It is not evident what the impact will be on their cash crops, which are primarily bananas, mangoes, lemons and guavas (FAO, 2017d).

Most of the households living in these zones also keep goats, which are the most vulnerable to climate change after cattle. Their vulnerability comes from the fact that while the potential impact of climate change on livestock is less than that on crops, there is limited adaptive capacity for many of them (FAO et al., 2017). Households also keep sheep, which are the least affected livestock group, especially in mixed farming systems such as this one. Therefore, maintaining sheep populations could be an effective adaptation strategy for these farmers. Breeding drought and heat tolerant sheep and goats will also be essential for maintaining herds and the livelihoods that depend on them in the context of climate change (Wenger, 2012). Other options for diversification could include poultry, which appears to be less exposed to the impacts of climate change than other animals (FAO et al., 2017). Even so, it is important to note that crops are the primary activity for most of these farmers, so diversification may only go part of the way towards building resilience (FAO, 2017d).

While there is a direct impact on the crops and livestock upon which these farmers depend for subsistence, there are other indirect impacts as well. Many farmers engage in other activities to supplement their income. For the most part, this is within the agricultural sector on larger farming systems. The overall impacts on agriculture in Sudan could threaten their employment opportunities since the entire sector would be under threat which could cause migration to urban areas in search of less resource-dependent employment. There are limits on the extent to which farmers can diversify their incomes given that many are illiterate. The trend to diversify into other farm or off-farm jobs as climate conditions become more unpredictable will change the farming dynamics. Women, and potentially children, will play a more significant role on the farm because it is primarily the young men who will be searching for other employment opportunities (FAO, 2017d).

Impacts on Sudanese semi-nomadic and nomadic farming systems

Some of the highest temperature increases in Sudan are in the semi-nomadic and nomadic farming systems, with increases of 2.6-3°C in RCP 8.5. The Nile Valley is due to suffer the highest potential impacts and is one of the most vulnerable areas in the region for livestock, which will negatively impact the semi-nomadic cattle herders more than the nomadic camel herders because these small-scale partly sedentary producers lack mobility and access to relatively good pastures. For nomads, camels – especially those that have a very low density – are highly exposed to the impacts of climate change. However, they have a greater adaptive capacity than cattle because of their ability to survive without water and sustenance for extended periods of time (FAO et al., 2017).

It has been recognised that cattle that are the most vulnerable to the impacts of climate change. Furthermore, they are more affected under grassland systems such as the ones dominant in this area rather than the mixed farming systems observed further south. As rainfall patterns become more erratic, the livelihoods of these semi-nomadic herders could be particularly impacted as the dry season grazing will experience a fall in the quantity and quality of forage. This could be more pronounced in western parts of this farming system where precipitation could drop by up to -7.9 mm/month in both RCP scenarios, but more extensively in RCP 4.5. Crop residues and stubble will therefore likely continue to be used to supplement grazing (FAO et al., 2017). Also, access to early warning early action systems will help semi-nomadic and nomadic farmers plan their movement, manage maintenance and selling of their assets more efficiently.

Herders' diversification into ruminants, such as they are already doing with goats and sheep, is a method of adaptation for the 8.9 percent of the Sudanese population engaged in nomadic lifestyles. This trend will also bring women more integrally into the economy as they are currently responsible for the management of small ruminants in semi-nomadic and nomadic systems. It is important to note that the sheep belt in Sudan will still suffer the negative impacts of climate change, including erratic rainfall, floods, droughts and land degradation. These impacts are a problem for pastoralists and the area more generally since sheep are the number one commercial animal in Sudan (FAO, 2017d). A reduction in both quantity and nutritional quality of forage will result in reduced meat and milk supplies to markets, and the necessity of selling off livestock assets to maintain flock size which will severely limit the livelihoods of both nomads and semi-nomads who rely on selling these products in the country along short and long value chains.

Impacts on Egyptian irrigated farming systems

As with the small-scale farmers in Sudan, these farmers in Egypt do not depend solely on agriculture for their livelihoods. In fact, full-time employment in on-farm work declined from 73.3 percent in 1990 to 50.7 percent in 2010 for small-scale farmers. This is partly because the income from agriculture at this level is insufficient to cover the living costs of families. Somewhat dissimilarly from Sudan, most people who seek employment off-farm are still broadly engaged in agriculture through activities such as animal and poultry rearing, services and sales, and agricultural machinery services of craft work. While the overall trend has been towards a diversification of rural, agricultural work, this has fluctuated somewhat based on the viability of alternative employment opportunities (FAO, 2017e). Nevertheless, this dynamic suggests that small-scale farmers in Egypt are already prepared for the need to diversify their incomes, which will be important in the face of the changing climate conditions.

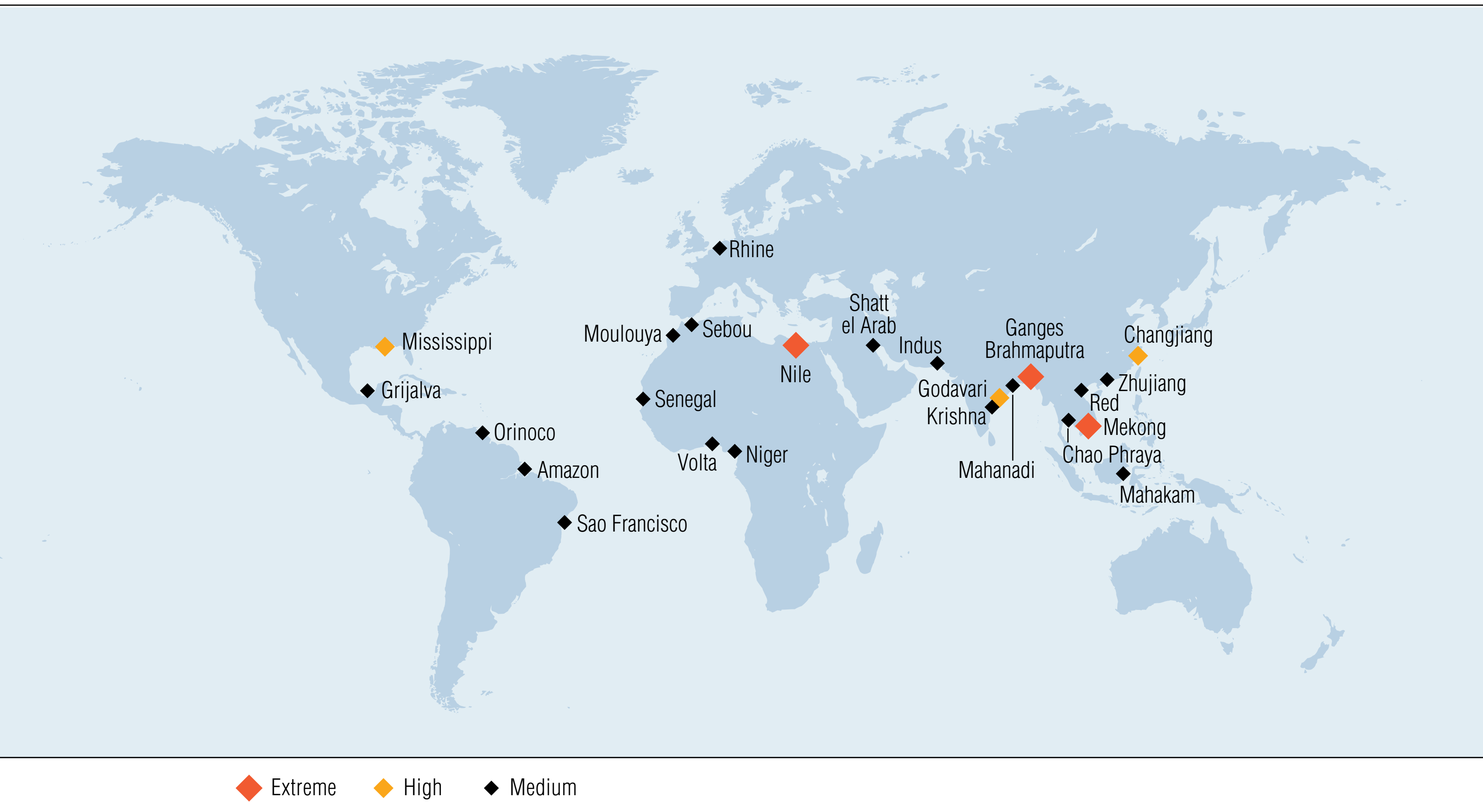
The Egyptian farming systems are remarkably, yet understandably, less diverse than those further up the Nile River. Most small-scale farmers – 94.8 percent in fact – irrigate their farms with water from the Nile River. Only around 5 percent use other sources of water for irrigation, such as groundwater, agricultural draining water, blended water or rain, which suggests that projected decreases – and increases in some areas – of precipitation will have limited direct impact on small scale farmers (FAO, 2017e). nevertheless, it is important to note that almost all of the farming systems along the Nile River in Egypt experience up to a -1.9 mm/month reduction in precipitation.

As with the Sudanese portion of the Nile River, Egyptian small-scale farmers cultivate field crops for their own consumption. In 2010, 91.4 percent of small-scale farmers' crop was field crops (such as cereals, legumes, sugar crops, oilseeds and forages) and only 8.6 percent was horticultural crops (such as fruits and vegetables), which generally require less water. Only surplus field crops were sold to the nearest market (FAO, 2017e).

Wheat is one of the three major cereal crops on which small-scale farmers are dependent for subsistence. Climate change will reduce wheat yields substantially, but the impact will be somewhat less on the irrigated wheat that these farmers depend on as compared with rain-fed wheat elsewhere in the region. Given the impact, it is suggested that future plant breeding programmes select new wheat genotypes that have higher sink capacity for photosynthetic products and are capable of increasing nitrogen uptake under elevated CO2 levels (FAO et al., 2017).

Maize is also an important cereal crop for the continuity of these farmers' livelihoods. Farmers consume it themselves, but it is also used as animal feed in the integrated crop-

Figure 15. Relative vulnerability of coastal deltas by the indicative population potentially displaced by current sea level trends to 2050.



Source: (IPCC, 2007)

livestock systems that are traditional in these farming systems (FAO, 2017e). Declines in this crop are less significant than those observed with wheat, with a range of zero to four percent by the mid-century

in a moderate and worst-case scenario, respectively, because maize benefits from the increased levels of CO_2 in the atmosphere as a C4 crop. While this limited change in maize yields in response to temperature and precipitation change is helpful for the integrated crop-livestock systems of these farmers, maize is mostly grown in the Nile Delta, which will experience other challenges resulting from climate change (FAO et al., 2017). Namely, the Nile Delta is one of the most vulnerable areas to the impacts of climate change-induced sea level rise (Figure 15) (Batisha, 2012).

While the Nile Delta is likely to experience lower temperature rises (1.6-2°C in RCP 8.5), some parts of the area – where the majority of Egypt's small-scale farmers live – are vulnerable to seawater intrusion that will flood and salinise the agricultural lands. Coastal flooding and/or permanent inundation of these areas would lead to a decline in water quality in coastal freshwater lagoons and corresponding adverse impacts on fisheries and biodiversity. Seawater intrusion is projected to also leak into the freshwater aquifers that these farmers depend on for irrigation as well as drinking which will have major impacts on the livelihoods of those living in the delta. The Nile Delta is home to approximately 40 million Egyptians and ranks among the world's most fertile farming areas. It accounts for around 90 percent of Egypt's agricultural output and more than 50 percent of its economic activity through agriculture.

In a country like Egypt, that does not produce sufficient food for its current population, any loss of its agricultural land due to sea level rise will have a direct adverse impact on the livelihood of millions of people and lead to hardship throughout the entire economy. Farmers will necessarily have to leave their land in cases of flooding and fertile land loss or, where possible, various adaptation methods will need to be employed. For example, farmers may need to adopt salt-tolerant crop varieties as well as crop rotation that could improve soil fertility and combat soil deterioration. Precise land levelling and cultivation of crops on raised beds are other options for farmers to maintain their productivity (Ouda et al., 2016). Portions of the Nile Delta are projected to receive precipitation increases of 0.1–2 mm/month, which could provide these farmers with an alternative source of water if water harvesting is correctly managed.

There are no pertinent data for the impact of climate change on rice for the region, but given its water-intensiveness, it may be a challenge for small-scale farmers to continue to produce it sustainably. Varieties with a growing period of 90 days in lieu of 120 days could be adopted to reduce water demands, which could additionally offer farmers the option of growing other crops in the 30 days saved. The Egyptian government is already attempting to reduce the area cultivated with rice as part of its sustainable agricultural strategy (Hadid, 2009). This does not, however, extend merely to rice cultivation. Most small-scale farmers along the Nile River and Delta in Egypt use tradition flood irrigation, which is highly water-inefficient. With constrained water resources in the future, this system of cultivating crops will no longer be a viable option for farmers (FAO, 2017e).

Livestock experience many of the same challenges along the Nile River and Delta in Egypt as those in Sudan. The main salient difference is that integrated crop-livestock management is more systematically adopted in Egypt. This will be increasingly important given the greater reliance on cattle and buffalo over sheep and goats that will leave farmers more exposed. Such diversification will build the resilience of small-scale farmers to changes resulting from climate change. Furthermore, in the specific context of the Nile Delta, some crops used for livestock grazing – such as clover – will be lost and farmers will need to find alternative sources of feed (FAO, 2017e).

Interaction with non-climate stressors

Climate change will act as a risk-multiplier on top of a series of interconnected non-climate stressors. The major challenges for small-scale farmers dependent on the Nile River are the transboundary issues between the 11 countries in the Nile Basin (Wu and Whittington, 2006). Also, both Egypt and Sudan suffer from poor natural resource management that leads to soil erosion, loss in soil fertility and deforestation (in Sudan) amongst other factors. Additionally, there is a trend towards land fragmentation and disputes over tenure that result in short-term, unsustainable management of land. These challenges are then coupled with increasing population pressures and urbanisation which place further strain on resources. Each of these factors interact with the impacts of climate change to make the conditions of the resources that small-scale farmers depend on less productive and less reliable (FAO, 2017e). These trends will push the small-scale farmers in this area closer to the margins than they already are, necessitating their employment diversification, changing their farming and family dynamics, and potentially engendering a more systematic migratory trend in search of more reliable livelihood options.

CIFS 4: North and West Iran

Farming systems and livelihoods

North and West Iran are dominated by two farming systems: highland mixed and pastoral. The highland mixed farming systems lie along the two mountain ranges in the country: the Zagros Mountains to the west and the Alborz Mountains to the north.

In the Zagros Mountains, the major crops are wheat and barley, which are grown alongside each other in the northwest of the country, whereas wheat alone is predominantly grown on the western side of the Zagros Mountains, and barley alone is grown east of the mountains. In addition to these cereals, fruits such as figs, pomegranates, melons and grapes are also grown. Vegetables, cotton, sugar beets, sugarcane, olives, raisins, tobacco and barberries are also grown (Danish Agriculture and Food Council, 2017).

Wheat and barley continue to be cultivated along the Alborz Mountains with pockets of barley exclusively grown. In the northern foothills of the Alborz Mountains (i.e. along the Caspian Sea) rice and tea are predominantly cultivated. Citrus is also cultivated. In this area of the mountains, there is large forest cover. As with the Zagros Mountains, a variety of fruit and vegetables are also cultivated in the Alborz Mountains.

In both the north and west of Iran, livestock are kept alongside crop production. Sheep are the most commonly kept livestock, followed by goats, cattle, donkeys, horses, buffalo and mules. Poultry are also kept for eggs and meat. Most farmers work through cooperatives.

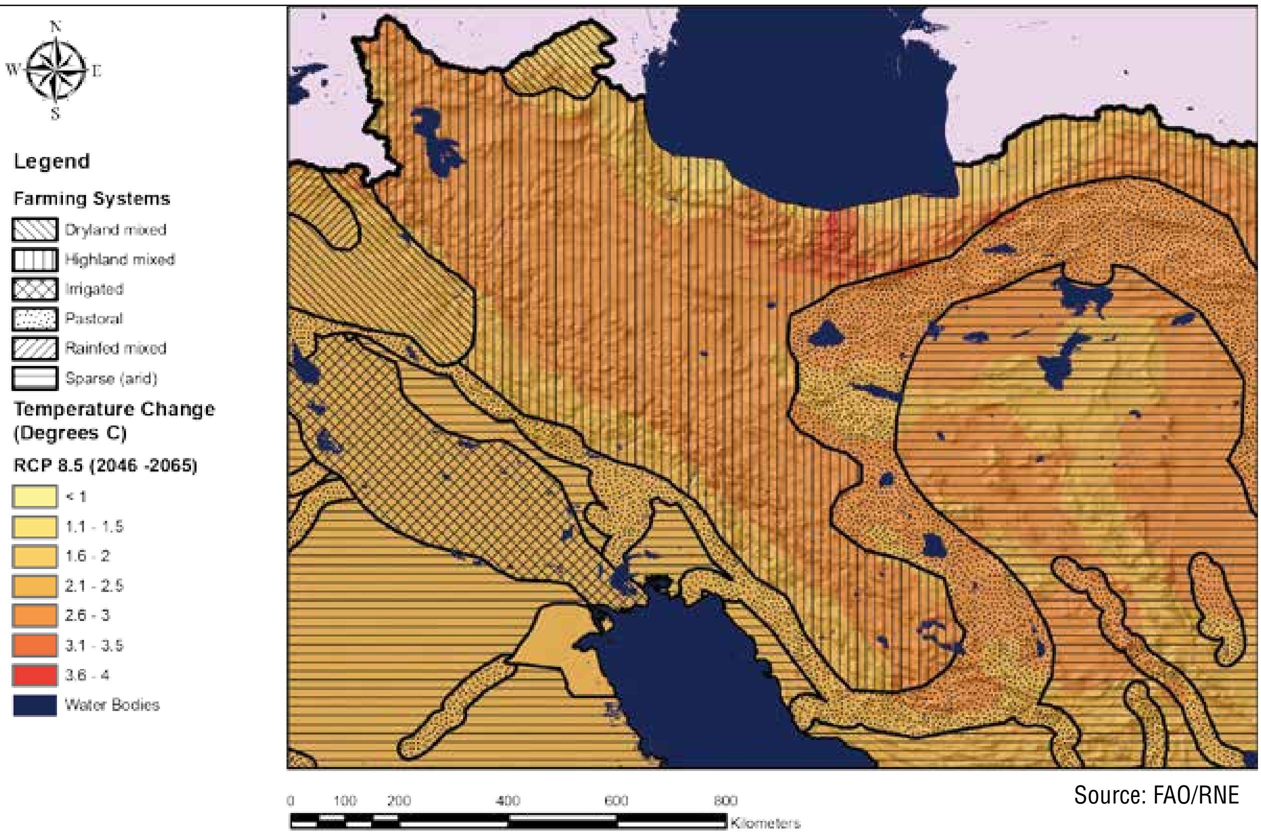
Pastoral land lies directly inland of these two highland mixed farming systems. As with the mixed farming systems, pastoralists primarily keep sheep. In the south-west, pastoralists are in large part members of the Qashqa'i tribal confederacy, an ethnic minority in Iran. The Qashqa'i were nomadic pastoralists who migrated semi-annually until the 1960s when they began to settle in villages and towns. This transition saw the diversification of their livelihoods, while still retaining pastoralism as one of their sources of income (Beck, 1998). Pastoralists further north are not characteristically nomadic.

Climate change trends and impacts

By the mid-century, Iran generally is expected to experience some of the most dramatic changes in temperatures in a worst-case scenario (Figure 16). Most of the agricultural land is projected to witness a temperature increase of between 2.6–3 °C by this time, with a particularly high increase of 3.6–4 °C projected for the central Alborz Mountains. While the worst-case scenario is dramatic, the moderate scenario shows that the greatest increase in temperature for the region also lies in the central Alborz Mountains and northern Zagros Mountains (RICCAR, 2017).

The north and west of Iran observe a general increase in precipitation by the mid-century under both moderate and worst-case scenarios. This increase is most notable in the northern

Figure 16. Change in annual mean temperature in Iran under RCP 8.5.



Source: FAO/RNE

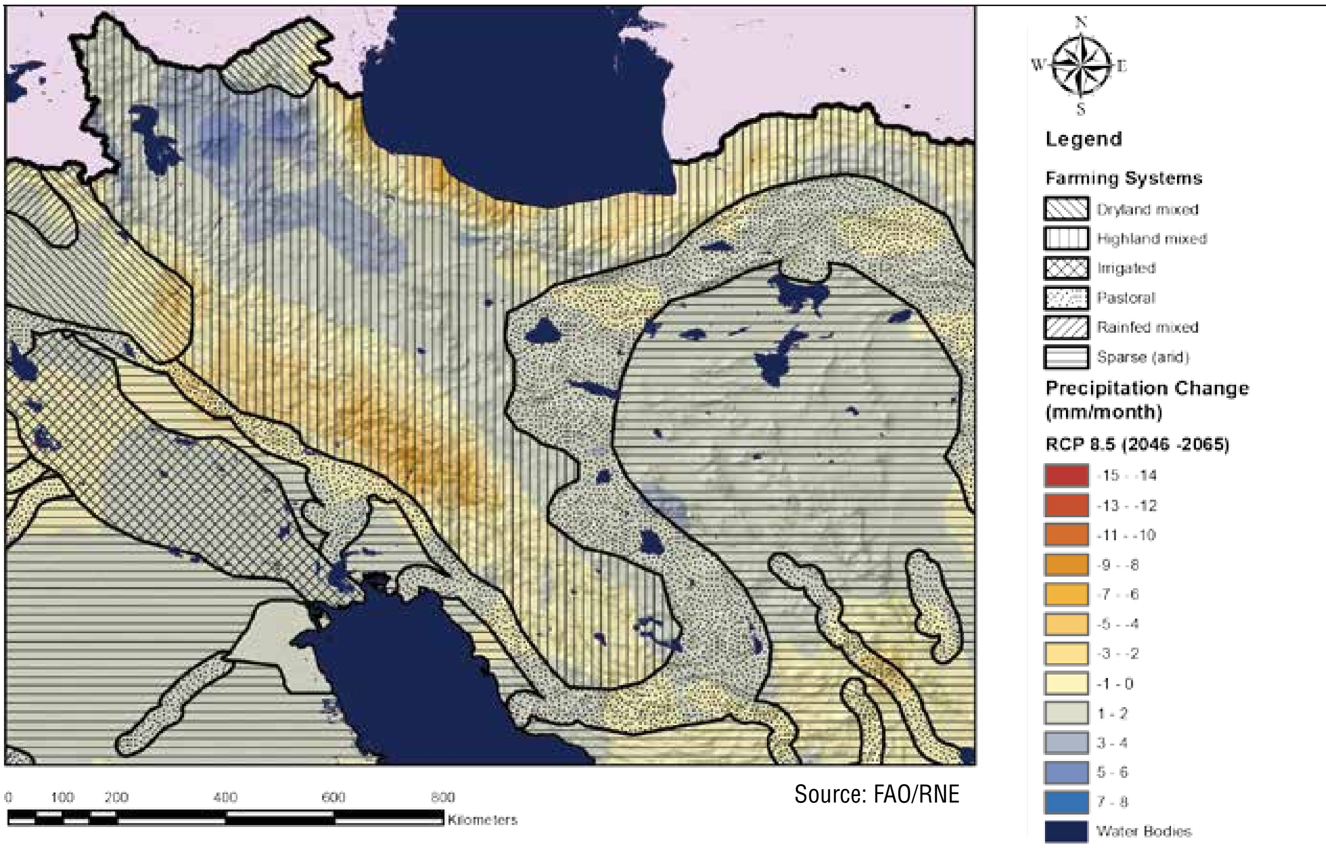
Zagros Mountains and central Alborz Mountains where precipitation changes are expected to exceed 5 mm/month. In a worst-case scenario, while the eastern Zagros Mountains and the southern Alborz Mountains are expected to observe increases (albeit more moderate ones) in precipitation, the western Zagros Mountains and northern Alborz Mountains are set to observe decreases of at least -1 mm/month and at least -4 mm/month in some areas, including the central Zagros Mountains (Figure 17). These decreases could have strong implications since it is these areas that have the highest levels of precipitation in the base scenario and can, therefore, be presumed

to be more reliant on precipitation for agriculture. In the case of the central Zagros region, this area is also already impacted by sand and dust storms (RICCAR, 2017).

Impacts on highland mixed farming systems

Wheat production areas on the western side of the Zagros Mountains are likely to undergo yield losses as this area will observe some of the most extreme changes in temperature (2.6-3°C in RCP 8.5) and certainly precipitation (up to -7.9 mm/month in RCP 8.5). Water deficits for wheat are projected to be around 23 percent during the growing season by 2050 which may result in farmers altering their planting dates or indeed switching to other crops, such as barley

Figure 17. Change in annual mean precipitation in Iran under RCP 8.5.



Source: FAO/RNE

(Michel, 2018). The switch to barley is already happening in parts of the country. However, since barley is predominantly used for livestock fodder, this would mean an alteration in human food consumption patterns. This dynamic is complicated by Iran's subsidy programme, which includes heavy subsidies for wheat and agricultural water use. Water subsidisation has resulted in usage rates for cultivating wheat between two and three times greater in Iran than the global average (Michel, 2018). Developing mechanisms for encouraging more efficient water use would ensure that farmers were able to continue wheat production more sustainably. Fortunately, small-scale farmers also cultivate fruits and vegetables in most of the Zagros Mountains. For the northern Zagros Mountains, while precipitation is expected to increase (by between 4.1-6 mm/month in RCP 8.5), precipitation intensity will increase as well. In a mountainous area, the resulting floods and soil erosion could limit production. Methods for anticipating and adapting to such flooding will be important. This applies to the fruits and vegetables also cultivated by small-scale farmers in this area, which provide them with alternative food and income sources.

Rice – one of the major crops grown in the Alborz Mountains – may observe reductions in production and productivity that result from the increased temperatures, particularly in summer. In fact, the central Alborz Mountains are likely to experience the most extreme temperature rise in the region of up to 4°C (RCP 8.5). Furthermore, under a moderate scenario, there is likely to be an increase in precipitation of 3–6 mm/month, which could result in flooding that will damage rice yields (RICCAR, 2017). Increase precipitation may force small-scale farmers to change their planting times or cropping patterns. Iranians are, however, already breeding rice varieties that will increase their resilience to changing temperature and precipitation patterns.

Tea – the second major crop in the Alborz Mountains – is also likely to feel the impacts of climate change. Reduced precipitation will be a major constraining factor for the growth of tea. Projections suggest that this will be a greater problem in a worst-case scenario than a moderate one, with precipitation dropping by -6 to -7.9 mm/month on the northern side of the mountains. The above-regional-average temperature changes could cause the soils to dry and consequently reduce yields. Applying mulching can help to mitigate this risk. Increased temperatures are also likely to increase the incidences of pests and diseases on tea bushes. It is possible that the temperature increases in the central Alborz Mountains area may become too high for tea cultivation and therefore new areas might be sought by farmers to plant the crop. There are effectively no other parts of Iran that are suitable for tea production (Chang and Brattlof, 2015; Michel, 2018). Therefore, increasing the production of other crops will likely become necessary for small-scale farmers.

In all cases, diversification is inhibited given the challenge of land fragmentation that constrains farm size. However, the prohibition of the inheritance system that encouraged such fragmentation may ease some of this pressure on small-scale farmers. More significantly, agricultural cooperative units with collective ownership rights that were established after the 1979 revolution (known as mosha) are relatively strong and could act as a means of profitably diversifying agricultural livelihoods (Abdollahzadeh et al., 2012).

Further east, saffron and barberries are grown, both of which are high-value crops. The reduction in rainfall – interestingly projected to be more severe in a moderate scenario than a worst-case one – and the desertification brought about by increases in temperatures (2.6-3°C in RCP 8.5) are predicted to affect the yields of this crop (Husaini, 2014). There is evidence that barberries may respond positively to increases in temperature. Since these two crops are often grown together and are harvested at the same time, small-scale farmers may need to adapt their cropping patterns to maximise yield (Merow et al., 2017).

With potential yield losses in cash crops, options for strengthening market access – which is notably weak for small-scale farmers in Iran – will need to be prioritised to ensure incomes can be sustained. It is interesting to note that several the high-value crops, including dates and pistachios, are largely grown outside of the most impacted areas in the country. Nevertheless, they are still in areas that witness changes in both temperature and precipitation.

In both the north and west of the country, most small-scale farmers also keep livestock, mostly sheep. Sheep are the least affected livestock group, and this is especially the case in mixed farming systems such as those in Iran. Maintaining sheep populations and breeding drought and heat tolerate sheep could be an effective livelihood adaptation strategy for these farmers (FAO et al., 2017). Since poultry is already being kept throughout these regions, this could be another adaptation option to build the resilience of small-scale farmers' livelihoods. Given some of the stark conditions for farmers in these areas, diversifying out of agriculture may – and already is –an option to be pursued. Diversification may have ramifications on the

Water-Energy-Food Nexus

Water, energy and food resources are interlinked in a complex nexus. The availability, use and management of these three resources have direct and indirect impacts on the sustainability and the security of the other two. These interlinkages are highly pronounced in the NENA region where the challenges of water scarcity, energy intensity and food insecurity are all compounded by the region's population growth and vulnerability to climate change impacts.

The interdependencies, risks and tradeoffs associated with this nexus are yet to be reflected in the institutional settings of most NENA countries. The three sectors are commonly administered by separate governmental entities at national, provincial and local levels. The fragmentation and resulting sectoral approaches to planning and policymaking in each sector reduce the opportunity for consideration of the risks associated with a given plan or policy in one sector on the others. This is brought to light with the high dependence that many NENA countries have on water and energy subsidies. As climate change necessitates policy shifts on subsidies, this will have implications for small-scale farmers who depend on these subsidies and who are vulnerable when water, energy and food policies operate in siloes.

national economy since agriculture employs around 33 percent of Iranians (Karbasioun et al., 2008).

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Impacts on pastoral farming systems

Pastoral communities are not projected to undergo the direct impacts of climate change with the same severity experienced by crops. Despite projected temperature rises (2.6-3°C in RCP 8.5 for most pastoral lands), many areas where pastoralists are dominant will likely see a modest increase in precipitation of 1–2 mm/month in both moderate and worst-case scenarios. However, the challenge is that the overall adaptive capacity of livestock is lower than that of crops, which has negative implications for the livelihoods of the small-scale farmers who are dependent on them unless options for protecting or diversifying their subsistence and income sources are developed. Fortunately, most pastoralists in these areas are largely dependent on sheep, which are the least exposed to the impacts of climate change. As with the non-pastoralists in this area, diversifying herds and breeding for drought and heat tolerant conditions will be important to sustain this livelihood. Fortunately, many of the tribal and non-tribal nomadic groups are already moving into urban and peri-urban areas where they are engaged in other income-generating activities (Beck, 1998).

Interaction with non-climate stressors

There is a series of agricultural and natural resource management policies that have depleted the land and water resource base, which in turn will reduce the resilience of small-scale farmers to the impacts of climate change. The government has worked to improve the country's food security partly through the subsidisation of agricultural water use, electricity and fuel over decades. However, this has resulted in the overexploitation of water and, in some cases, desiccation of land. The 2010 Targeted Subsidies Reform Act aimed to cut energy subsidies, raise electricity and water charges, and remove food subsidies. However, the cash transfers that were intended to replace these subsidies could not be afforded with the dividends from the subsidy savings. As such, the reform was discontinued after the first phase (Michel, 2018).

Therefore, the unsustainable use of water remains a factor that will make small-scale farmers less resilient to the impacts of climate change, which will be the case particularly with extreme

Climate change in Oman

For Oman, rising temperatures and the associated heat stress along with sea level rise and reduced precipitation will impact agricultural production and productivity. This is exacerbated by the over-abstraction of groundwater. The only major farming system specified in the CIFS for Oman is pastoralism. Pastoralists in Oman are likely to be exposed to the same challenges that result from changes in temperature and precipitation as in other parts of the NENA region. Their challenges centre around reliable access to water. While cattle, sheep and camels are kept, goats–which are relatively less vulnerable to climate change–are the most common ruminant. In a changing climate, early warning early action will be key to informing their movement patterns.

While not identified in the CIFS maps as one of the major farming systems, small-scale Omani farmers operate crop and mixed farming systems. The most important agricultural activities are in the coastal regions of Al-Batinah and Salalah. Horticulture and fruits (including bananas, dates, limes and mangoes) and cereal production dominate these areas, which will be most adversely affected by climate change where temperature increases will result in increased evapotranspiration to 7.15 mm/day by 2050, up from the current level of 4.5 mm/day. Higher temperatures, tropical cyclones and flash floods jeopardise the water supply from the Aflaj irrigation systems as well as other irrigation systems that many of these farmers depend on.

In addition, sea levels in the area are expected to rise by 24 cm by the mid-century leading to salinisation of agricultural lands. This increased salinisation of coastal agricultural land has occurred at a faster rate than the development of new agricultural land. This trend resulted in Oman's area under cultivation decreasing by 8.3 percent between 2000 and 2007. As such, many farmers have already abandoned their land.

These impacts will threaten the already-fragile livelihoods of Omani farmers who are already experiencing low crop and livestock productivity, leading to Oman's dependence on imported agricultural products. These trends are already pushing small-scale farmers to diversify into off-farm activities to supplement their livelihoods or to leave agriculture altogether. It is worth noting the government's efforts to assess climate change effects to better address the challenges affecting various sectors are underway, including the best ways to support smallscale farmers.

events such as heatwaves and droughts. Iran is accustomed to prolonged droughts of five to six years every decade. However, climate change is likely to augment the frequency and intensity of droughts and–alongside a depleted natural resource base–the impacts of such droughts on agricultural livelihoods will be that much more pronounced.

Finally, as with Iraq, Jordan and Syria, the prevalence of sand and dust storms is a growing issue that is limiting agricultural productivity. This challenge itself is also being exacerbated by climate change as soils lose their moisture and fertility (UNEP et al., 2016). As such, Iran, which is already using more than 80 percent of its renewable water, is rendered one of the most water-stressed states in the world. The adverse effects of climate change will force Iran to face numerous intensified water security challenges combined with land degradation, desertification, drought, sand and dust storms, the loss of forest cover, vegetation, and biodiversity. Aware of this nexus of challenges, the government is taking active steps to address it (Michel, 2018).

CIFS 5: Yemen

Farming systems and livelihoods

Before the outbreak of conflict in Yemen, agriculture and fisheries contributed between 18 and 27 percent of Yemen's gross domestic product, 25 to 30 percent of the annual food requirement and employed more than 50 percent of the country's workforce (World Bank, 2015). This economic dependence on agriculture has been growing due to a lack of viable alternative livelihoods. This trend is unique to Yemen with what is observed throughout the rest of the region.

Around 53 percent of Yemeni households practice agriculture and consider it the main source of income and livelihood. There are three main agriculture-farming systems in Yemen: crop farming, livestock farming and highland mixed farming. Most agricultural households practice mixed farming. At the national level, almost half (48 percent) of households practice mixed farming with crops, cattle for dairy consumption and small ruminants as a source of cash to supplement family expenditures.

Second to these highland mixed farming systems, is livestock rearing which is practised in 40 percent of farming households. Households mostly keep small ruminants, especially sheep and goats because they can access cash faster by selling these ruminants than by selling larger animals (EFSNA, 2016).

Cereals (mainly wheat, sorghum, millet and barley), qat, coffee, fruit and fodder crops constitute 80 percent of the crop production (Figure 18). There is some limited irrigation that is used for the cultivation of horticultural and field crops. Nevertheless, Yemen still imports around 90 percent of its staple food which suggests that while many Yemenis' livelihoods depend on agriculture, they are still dependent on international markets for their food security and nutrition (FAO, 2017). Additionally, the conflict has negatively impacted agricultural production with a nearly 40 percent reduction in overall production due to reduced acreage under cultivation and expensive agricultural inputs (EFSNA, 2016). The shortage of fodder and veterinary services has resulted in livestock production declines (EFSNA, 2016; EFRLP, 2017). This decline has severely affected small-scale farmers' livelihoods.

Climate change trends and impacts

Strong changes in both temperature and precipitation are projected for the coastal highland mixed farming system in Yemen, which is especially the case along the south-western border of Yemen, in the mountainous lands. In the moderate scenario, this area is expected to observe a 1.6–2 °C increase in temperature by the mid-century. In a worst-case scenario, it is projected to increase to 2.1–2.5 °C. Given that this area observes the lowest annual temperatures in the base period, these comparatively large changes could result in major implications for the communities living in these areas.

Unlike many other parts of the region, changes in precipitation are likely to be more noticeable under a moderate rather than a worst-case scenario. A 4–7 mm/month decline in precipitation is observed in the moderate scenario. Al Hudaydah, Dhamar, Ibb and Taiz governorates are seen to suffer the greatest changes in precipitation. It is these areas that receive the largest amount of rainfall in the base scenario, and it is, therefore, reasonable to assume that the impacts will, therefore, be even more pronounced (RICCAR, 2017). Given the small and declining importance of pastoralism in this area and the fact that pastoral lands are not in the most-impacted zones, the implications for this system are not discussed in this report.

Impacts on highland mixed farming systems

Small-scale farms are currently growing cereal crops that are largely heat and drought tolerant, namely sorghum and barley. These crops will be important because these communities farm largely for subsistence and their lands are likely to become more arid and experience a greater risk of drought in the context of climate change (World Bank, 2015). Of the three major cereal crops, it is millet that – as a summer crop – is likely to incur yield losses due to rising temperatures (2.1-2.5°C in RCP 8.5) that may be more pronounced in summer

(FAO et al., 2017). Rising temperatures may require small-scale farmers to switch to growing more sorghum and barley given the reduced precipitation projections. Overall, crops may benefit from longer growing periods because of rising temperatures in these mountainous areas. While the extent to which this may be the case is unknown, it will be important to optimise crop calendars (FAO, 2018) since there is only one planting season for several crops.

Aside from some coastal areas that may experience increases in precipitation (especially under RCP 8.5), there is a general drying trend of between -4 and -7.9 mm/month reduction in both scenarios. In addition to temperature and precipitation changes, there is likely to be an increase in erratic weather, including both droughts and floods that are likely to exacerbate runoff, erode soil and therefore contribute to yield losses. In recent years, Yemen's rainfall patterns have shown increasing extremes that have been attributed to climate change and variability. The country suffers from "absolute water scarcity", with an Internal Renewable Water Resources rate of less than 100 cubic metres per inhabitant per year. Frequent droughts and flash floods have already affected crop production, livelihoods and income generation for a large percentage of the population. Many households also face the threat of crop failure because of pests and diseases, sandstorms and land degradation – all of which further threaten their food and nutrition security. Being able to manage post-harvest losses will become even more important for the subsistence of these farmers as such extremes become more likely.

The lucrative qat crop is grown on irrigated lands and is a key pillar of many farmers' livelihoods. However, it is highly water-intensive compared with other crops, using 40 percent of the country's water resources and 38 percent of the irrigated land, which could be used for other crops (World Bank, 2016). Climate change is likely to increase the demand for irrigated crops, which may lead to competition for irrigated land between cash and staple crops. This challenge will be compounded by the rapid population growth in Yemen that is triggering a transition towards cash crops. Not only are these crops generally more water-intensive, they take up arable land that could be used for edible crops. Fewer edible crops means less access to food for these small scale farmers. Indeed, as it is now, water will continue to be the most constraining resource in a climate change affected future. Prioritizing the management of agricultural water resources will be even more necessary in the coming decades. In fact, the issue of water is so pressing that its management extends beyond the confines of agriculture to the amount of water that these farmers will have to drink (World Bank, 2016).

Despite the challenges for crops in this system, around 90 percent of the food supply to Yemen, small-scale farmers included, is imported (FEWS, 2018). Therefore, they are also acutely vulnerable to the impacts of climate change in other regions and the geopolitical shifts that could alter food prices on the international market.

Fortunately, while the impacts on crops are complex, small-scale farmers already keep mixed crop-livestock systems with a relatively strong diversity of breeds and species. Goats and sheep are the most commonly kept ruminants. This diversity builds the resilience of farmers to the impacts of climate change. Emphasizing maintenance of goat and sheep populations over cattle ones may be a more impactful adaptation priority in the context of climate change since they largely suffer the least potential impact (FAO et al., 2017).

While the mixed crop-livestock systems suggest that small-scale farmers will have some inbuilt resilience to the impacts of climate change, these impacts will still occur within the context of a fragile state that is dealing with a protracted armed conflict. Any climate change impacts, even minor alterations or unpredictability, could have more dramatic effects in conflict zones than in non-conflict zones. There will be a need to strengthen market access and marketing systems–which are currently weak–to manage these farmers' livelihoods, especially for cash crops.

Interaction with non-climate stressors

These challenges will occur in the context of the protracted conflict between the Houthis and Yemeni government that has been ongoing for many years, but which escalated in 2011 (with the Yemeni Revolution) and then again in 2015 (with the Yemeni Civil War). This conflict has resulted in both agricultural and non-agricultural assets being lost, destroyed or degraded, causing extensive damage to livelihoods, high unemployment rates and leaving an estimated 17.8 million people food insecure (IPC, 2017).

The destabilising effect of this conflict began in the north of the country but rapidly spread south to the mountainous coastal region where most small-scale farmers live. The lack of stable government, constant tribal grievances, inefficient management techniques and the land fragmentation which resulted from the conflict make the development of political and technical solutions impossible or short-lived. Thus making the regulation of water-intensive agricultural practices very challenging. Attempts to regulate water demand have included increasing diesel prices, removing credit subsidies for agriculture, altering the fruit and vegetable ban, regulating and taxing the use of groundwater, and developing water productivity projects (World Bank, 2016). Limited development capacity and a lack of effective tools for implementation have impeded these measures.


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SOCIOECONOMIC AND LIVELIHOOD IMPLICATIONS

Food security and malnutrition

The most direct impact of climate change on small-scale farmers in the region will likely be a reduction or increased variability in their food supply. The potential of reduced agricultural productivity and production will mean that more of these farmers are at risk of hunger. Some climate change scenarios estimate that an additional 3.8 million people are at risk of hunger in the NENA region (IFPRI, 2017). There are direct undernutrition implications for farmers who are unable to grow enough food to feed themselves or to sell at market to buy other comestibles. Of the countries in the region, the occurrence of high levels of chronic malnutrition is still a challenge in seven countries, especially Sudan and Yemen (FAO 2016c).

Gender and migration

In poor rural communities, the development of effective strategies to respond to climate change hinges upon a full understanding of the differentiated risks that are faced by women,

men, girls and boys, as well as the equal involvement of women and men. Women, men, girls and boys have different needs, responsibilities and endowments, all of which are important factors in assessing adaptive capacity. In cases where small-scale farmers can no longer feed themselves or earn a decent living from agriculture, they will seek to diversify their livelihoods or transition to entirely new, off-farm ones as a strategy that aims to adapt and improve households' living standards during periods of shocks. Before adopting income diversification options, they may try to compensate for the short-term drops in income by using their stocks of capital to generate survival behaviours, or to sustain a standard of living above the line of deprivation. For example, farmers could consume their food reserves and wild foods, sell their livestock and other assets, or share their resources (Seaman et al., 2014). These coping strategies as well as farmers' livelihood diversification activities are being practiced in the region and are seen as both alternative forms of off-farm and non-farm livelihood activities.

In some cases, small-scale farmers will migrate from rural to urban areas to seek more lucrative forms of employment. Due to the prominence of occupational segregation of gender-specific employment in the region, adult males make up the group of individuals who leave the agricultural sector in search for other livelihoods opportunities in urban or peri-urban centres. Rural women who are married with children are therefore most likely to remain in villages, since women's entry into the labour force outside of agriculture is still impeded throughout the region.

Social structures and conflict

With increasing numbers of the men gone to cities, agricultural responsibilities are now disproportionately placed on women, along with older family members and the youth, who now constitute an important proportion of the stable work force in rural areas. The social and family structures are affected by these changes, although men are still the head of the household and they send remittances to their families that are mostly used to purchase food and other basic needs. It is also important to consider that the remittances sent back by those migrating could be used as part of a coping strategy. These changes to the family and social structures could also increase the reliance on child labour, which is already characteristically high in agriculture in the NENA region.

The socioeconomic impacts of climate change on small-scale farming do not end on the farm. In some cases, there will be competition for resources and employment in places that these farmers migrate to, which could lead to social unrest if the transition is not successfully managed to ensure the provision of productive economic opportunities. Conflicts over access to natural resources have already caused political instabilities in many countries and have even disrupted food availability and accessibility, which are the leading causes of child malnutrition (FAO 2017i).

Table 2. Summary of climate change impacts and responses by farming system

Farming System	Country	Agricultural impact	Livelihood impact	Responses*
**The responses specified here are complemented by the CSA practices outlined in policy recommendations sections*				
Rain-fed mixed	Maghreb	• Large yield reduction in wheat • Yield reduction for olive, citrus and dates • Yield reduction in potatoes in Algeria • Large yield reduction in maize, especially in Mauritania • Yield reduction in sorghum and millet, especially in Mauritania • Reduced dairy milk yield relative to feed for goats and sheep	• Food consumption patterns may change due to reduced wheat • Income from olive sales and exports to decrease • Food security jeopardized, especially in susbsistence-dependent areas	• On-farm diversification, including crop diversification • Develop heat-tolerant wheat varieties • Modify crop rotation and planting times • Consider increased reliance on sorghum
	Mashreq	• Reduction in olive yields, especially in central Lebanon and southern West Bank • Reduced dairy milk yield relative to feed for goats and sheep	• Income jeopardized • Continuation of the livelihood diversification trend, both on and off-farm	• On-farm diversification • Supplemental (especially drip) irrigation for olive trees • Change crop planting times
	Nile Valley (Egypt and Sudan)	• Yield reduction in millet, potato and tomato, especially in Sudan • Moderate yield reduction in sorghum, especially in Sudan	• Income jeopardized for both crop and livestock products • Subsistence and low education levels limit livelihood diversification	• Increase cultivation of sorghum, given lower vulnerability and shorter growing period • Breed drought and heat tolerant sheep and goats

		• Reduced dairy milk yield relative to feed for goats and sheep		• Diversify into poultry production
Dryland mixed	**Mashreq**	• Risk of agricultural land transformation into rangeland • Yield reduction in wheat and barley • Mountain and Shami goats impacted, but to a lesser extent	• Income jeopardized, especially in Syrian wheat belt • Necessity for livelihood diversification and potential migration	• Continued crop diversification including with cucumbers, tomatoes, eggplants and citrus • Promulgation of high-yield varieties of wheat that are heat and drought tolerant
	Maghreb	• Overall crop yield reduction • Goats and sheep impacted, but to lesser extent • Limited arable land and low water availability suggest few options for maintaining agricultural production	• Income jeopardized • Necessity for livelihood diversification and potential migration	• Off-farm diversification options due to farming system proximity to cities
Irrigated	**Nile Valley (Egypt and Sudan)**	• Wheat yield reduction • Moderate maize yield reduction • Field and horticultural crop reduction from salinization of agricultural land by sea level rise in Nile Delta • Cattle and buffalo health and production negatively impacted	• Income jeopardized • Food security of smallholders dependent on field crops for subsistence compromised	• Promote new wheat genotypes • Adopt salt-tolerant crop varieties • Crop rotation for improved soil fertility and quality • Precise land levelling and crop cultivation

				of raised beds in the Nile Delta • Implement alternatives to flood irrigation
	Mashreq	• Reduced irrigation water for rice, vegetables and sunflower production, especially in the Fertile Crescent • Crop yield reduction from soil erosion, floods and sea level rise, especially in the Shatt al-Arab / Arvand Rud • Moderate declines in maize yields • Moderate livestock declines	• Income jeopardized • Necessity for livelihood diversification and potential migration	• Optimize irrigation patterns • Continue diversification into non-agricultural labour, especially around urban centres • Continue crop and livestock diversification
Highland mixed	North and West Iran	• Wheat yield reduction, especially in West Iran • Rice yield reduction, especially in North Iran • Tea yield reduction, especially in North Iran • Saffron yield reduction, especially in North Iran • Potential barberry yield increase, especially in North Iran • Horticultural crop losses from floods and soil erosion	• Income jeopardized • Tea farmers pushed out of production zone in North Iran • Income changes from fluctuation in high-value crops such as saffron and barberries in North Iran	• Potential transition from wheat to barley • Develop flood early warning systems • Adapt planting times or cropping patterns • Breed heat-tolerant rice varieties • Apply mulching for tea plants • Adapt planting times for saffron and barberries since they are often grown together

				• Breed drought and heat tolerate sheep • Diversify into poultry production
	Maghreb	• Yield reduction in wheat, olive, plain and citrus (especially orange) trees • Reduced dairy milk yield relative to feed for goats and sheep	• Food consumption patterns may change due to reduced wheat production • Income from olive sales and exports to decrease	• Potential transition to barley instead of wheat • Develop heat-tolerant wheat varieties • Off-farm diversification, especially in Tingitana Peninsula
	Yemen	• Crop yield reduction and potential failure, including for barley and sorghum • Increased risk of pest and disease spread • Increased demand for irrigated crops • Increased competition between cash (especially qat) and staple crops	• Income jeopardized • Difficulty managing post-harvest losses	• Continue production of heat-tolerant crops, such as barley and sorghum • Optimise crop calendars • Effectively manage agricultural water resources • Emphasize maintenance of goat and sheep populations over cattle

Pastoral	**Iran**	• Sheep health, productivity and production reduced, but to lesser extent	• Need for livelihood diversification	• Non-agricultural livelihood diversification • Diversify herds and breeding for drought and heat tolerant conditions
	Maghreb	• Pastoralists are largely outside the projected areas that will suffer the most severe precipitation declines. • Reduced animal feeds • Increased animal heat stress • Increased risk of infection and disease	• Need for livelihood diversification • Need for increased mobility options to seek better pastures	• Adapt traditional management and mobile grazing strategies
	Nile Valley (Egypt and Sudan)	• Cattle, especially in Sudanese grasslands, highly vulnerable due to reduced mobility. • Camels vulnerable, but can adapt through moving to better grazing lands	• Reduced income from reduced meat and milk supplies to markets • Need to sell off livestock assets to maintain flock size	• Supplement grazing with crop residues and stubble • Early warning systems that support pastoralists to plan movement, manage maintenance and selling of their assets more efficiently •! Herder diversification into small ruminants

CONCLUSIONS AND POLICY RECOMMENDATIONS

Closing the science-policy gap

Science, and the evidence that it provides on climate change and its projected impacts, plays an essential role in policy decisions that lead to better outcomes. Science-policy interfaces are critical in shaping climate change governance and developing effective programmes that will respond to the true challenges. Science-policy activities can be distinguished from the production of scientific research. They are designed based on the understanding that the availability of evidence alone has not been sufficient to influence political outcomes, and they, therefore, aim to promote the use of this evidence in policy development processes. The purpose of evidence goes beyond simple synthesis, but it must maintain the objective neutrality of science. It includes the role of stimulating political debate about particular issues, where adequate policy processes to consider that evidence do not yet exist. (UNEP, 2017).

The demand for a close observation of the impact of climate change in the NENA region has recently been met through the establishment of the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR, 2017). Within the RICCAR project, future climate change data are generated through downscaling projections from three global circulation models (EC-EARTH, CNRM-CM5, and GFDL-ESM) exercised on the region using the regional climate model RCA4 to provide higher-resolution information (at 50 km). This report takes a step towards closing that gap by assessing the impacts of climate change data at the farming system level and identifying the implications that climate change has for policymakers who wish to support vulnerable farmers. Policies concerning small-scale farmers in the context of climate change will need to consider the strategic support that is provided to small-scale farmers to ensure food security in the region as well as the implications of climate change for poverty and hunger reduction for these farmers. Many countries in the region are already taking steps towards supporting these farmers to both mitigate the greenhouse gas emissions associated with climate change and to adapt to the impacts

Assessing the impacts

Governments need to assess how they can maintain their food security in a changing climate for a region that has relatively low productivity potential. Assessments of the changes in staple crop yields and productive zones under various climate change scenarios will be essential for informing governments on priority areas. Some of this information exists, but it is needed at the national and sub-national levels. With such information on how agricultural output might shift, policymakers will be able to determine better where they invest and where investments may be at risk. Such information will enable policymakers to enforce the capacities of small-scale farmers to ensure their productivity in a changing climate. Nevertheless, in some cases, it is likely that small-scale farmers' livelihoods will be based in areas that are no longer economically productive for investment. In these cases, it will be important for governments to consider the impact of macro-level policy decisions on the livelihoods of small-scale farmers and determine pathways for supporting the livelihoods of those whose livelihoods are based on these risky assets. The focus on small-scale farmers is as much about reducing their vulnerability as it is about the ramifications along the value chain. The assessment of this vulnerability is household and context specific (Seaman et al., 2014).

Managing agricultural transformations

Food security in the NENA region requires the support and bolstering of small-scale farmers' agricultural productivity. However, the secure supply of food throughout the region is not the only consideration. The creation of productive rural environments that encourage decent rural employment and provide the social security that enables sustainable livelihoods is also essential. Policies that work towards these two goals are often complementary. In the case of small-scale farming, this will require reinforcing on-farm capacity, developing social protection measures, and improving access by these farmers to finance.

Climate-smart agriculture

Small-scale farmers could be supported to adopt more appropriate crops, including, drought, salt, pest and heat-resistant crop varieties where possible. Crops that have shorter growing seasons may also be preferable. Selecting and breeding livestock that are better adapted to drought conditions could also increase the resilience of the mixed farming systems that dominate the region as well as the livelihoods of pastoralists. In addition to the selection of crop and livestock varieties, optimising tillage and farm operations can hedge against the potential yield losses. Such practices include adapting planting dates to changes in temperature and precipitation; increasing land levelling to better disperse water and filtration; optimizing tillage mulching practices; introducing organic matter through manure and green manure; placing a greater emphasis on winter rather than spring crops; improving water harvesting; and altering the fallow period to increase retention of soil moisture and organic matter (FAO, 2016a). These options are part of a compendium of climate-smart agricultural solutions that can be adopted and supported by governments. Some of these key responses to the impacts in specific farming systems are outlined in Table 2.

In addition to options specific to crops or livestock, integrated crop-livestock-forestry systems are suggested as a method for reducing risks by diversifying assets. Furthermore, effective on-farm planning and management will require a more precise monitoring of temperature and precipitation trends under these more uncertain and extreme conditions. With effective climate monitoring and early warning systems, yield losses can be minimised. This can also be used to develop subsequent climate or weather-index based insurance. Finally, climate change will necessitate better post-harvest management and storage to reduce the food loss and waste that could result from increased temperatures, precipitation, or pests and diseases. As part of this, small-scale farmers could also look to developing value-added products that have a longer shelf life (FAO, 2016a).

These practices need to fit within a broader natural resource management agenda in which appropriate attention should be given to (1) the revival and adaptation of older systems of rational, rotational grazing and land management, (2) watershed-based soil and water management rather than looking solely at farm-level, (3) the development of sustainable groundwater management systems, (4) sustainable soil and water management techniques for annual and perennial cropping, (5) conservation of the unique flora and fauna of the region (FAO, 2002)

Social protection systems and extension services

As the conditions for farming change and become less predictable, small-scale farmers will need to ensure they have access to protection for their assets and livelihoods if they are to continue to produce sustainably. Such protection can be more effectively provided in conjunction with the weather-based monitoring previously mentioned. With this, insurance and extension services can be targeted meaningfully. Strengthening extension services (including

low-carbon technologies) has been shown to be effective in other regions for convincing small-scale farmers to change farming practices in response to climate change. Changing farming practices can be accomplished by providing technical information and training on best on-farm management practices, such as those identified above. Farmer-to-farmer learning is also effective, such as through climate-smart farmer field schools.

Financial Support

Some countries have been investing in agriculture for decades. This investment has, however, largely been focused on irrigated farming systems that have the greatest potential for agricultural intensification. However, the impacts of climate change on rain-fed farming systems appears to be stronger or at least more direct, and it is on these rain-fed lands that most of the small-scale farmers in the region live. Improving access to credit for these farming systems would help manage the risks raised by climate change which could take the form of direct investment, targeted subsidies and micro-credit opportunities. Other services that could help facilitate such access include mobile telephone payment systems and affordable options for families to exchange money amongst themselves even if they are not living in the same area (Wenger, 2012).

Village savings and loan groups are also an option for members to pool resources and lend money, especially during lean seasons. Cooperatives and producers' organisations also have a fundamental role to play in ensuring that farmers can access information, extension services, micro-credit for infrastructure and markets. Such investment could help increase farmers' production, improve their productivity, and ensure harvests are better protected since farmers often want to build local infrastructure but do not often have access to credit to do so (Harvey et al., 2014). More specifically, it is important to note that access to credit in the context of climate change often focuses exclusively on disaster risk reduction. However, long-term slow-onset disasters need to be considered as well to address the spectrum of risks fully.

At the national level, the impacts of climate change may cause investments in agriculture to prematurely lose their value because if production drops, then the returns on investment will be insufficient to cover the initial financial outlay. The risk of these assets consequently becoming stranded may deter governments from investing in this sector (Caldecott et al., 2013). This could have a direct and negative effect on small-scale farmers and the broader food security of the region. In such a case, complementary policies to support small-scale farmers to diversify or transition out of agriculture should be explored in tandem.

Managing livelihood transitions

Securing the production potential of small-scale farmers in the context of climate change will go part of the way to supporting poverty, hunger and food security aims. However, in many cases small-scale farmers are still likely to move out of agriculture, thereby raising the already-high reliance on food imports. As such, governments in the region may need to consider reinforcing their trade policies to ensure food security in the absence of production by small-scale farmers. Also, supporting the creation and transition towards productive off-farm employment (including through other parts of the agricultural value chain such as processing or marketing) will be important to ensuring stable and sustainable demographic transitions.

While reinforcing capacities on farms will help small-scale farmers to manage potential yield losses and therefore sustain their farm-based income, the climate projections for the region suggest that small-scale farmers will need to continue their diversification into off-farm employment if they are to sustain themselves. Income diversification reduces vulnerability. Diversification options will need to be tailored to the specific circumstances at the sub-national level. Options for diversification can be somewhat limited due to varying levels of literacy and education, and gender. If agriculture is no longer a sustainable livelihood whatsoever for small-scale farmers, then seeking employment opportunities outside of agriculture will be necessary.

Policies and programmes that create sustainable off-farm employment would be beneficial for reducing the risk of distressed rural-rural and rural-urban migration which is especially important in a region that is already managing a complex nexus of migration flows. Urban and peri-urban areas are already facing challenges of growing populations and unemployment. Consideration of how growing population flows from rural areas will influence national socio-economics is essential for ensuring a smooth transition.

Contextualizing policies

Climate change will act as a risk-multiplier to the challenges already being experienced by small scale farmers in the region. Therefore, a holistic approach to managing the non climate stressors alongside the climate ones will be essential to ensuring sustainable livelihoods for these farmers. Foremost amongst these non-climate stressors is the sustainable management of natural resources. The agricultural, natural resource and land tenure policies in many of the countries in the region have resulted in overexploitation of natural resources that reduce the soil and land quality and quantity unsustainably (FAO, 2017a). The added stressor of climate change may result in many of these areas that are currently on the margins of productivity being pushed over the edge. There is a general need for reviewing and better enforcing agricultural policies in many countries in the region.

Additionally, many of these policies have prioritised irrigated agriculture which is understandable given the tendency towards agricultural intensification in a largely semi-arid to arid region. However, the vast majority of small-scale farmers live in rain-fed farming systems. Therefore, inclusive policies need to look to the management of these lands as well because is not only in the interest of the small-scale farmers but the food security of the region generally since it is these farmers that provide almost half of the agricultural production for the region. As such, ensuring the sustainability of their production in the context of climate change is not only a step forward for these communities, but for the entire NENA region.

Small-scale farmers are at the heart of farming systems and so a framework for action needs to focus on the mechanisms necessary for supporting them to be resilient to the impacts of climate change while still ensuring that broader food security needs of the region are managed. The impact of climate change on small-scale farming operates within a broader context that extends beyond the livelihoods of these farmers to the broader food security of countries and the region. Climate change has the potential to impact and exacerbate the availability, access, stability and utilisation of food, and therefore the food security of the NENA region. Regarding availability, NENA relies on food imports to meet around half of its food supply needs. Small-scale farmers supply around 80 percent of the remaining food requirements, with the remainder provided by larger agribusinesses. Shifting production zones and extreme events will alter the access, stability and utilisation of food both within NENA and in the regions on which it depends for its imports.

Managing food security in the context of climate change, therefore, needs to consider the support provided to small-scale farmers, but also how food imports are likely to be impacted. Governments will need to assess the projected impacts of climate change on crop and livestock production and productivity to manage the balance of food availability. A summary of these impacts is outlined in Table 2. Nevertheless, further assessments need to happen at the disaggregated level alongside household-level economic assessments to determine the impacts on livelihoods, which in turn will have broader implications for the management of livelihood transitions and potential migration flows. Production and productivity changes should also be considered at the aggregate level. The latter will enable policymakers to develop support and investment efforts appropriate to certain areas.

In line with countries' stated priorities in their Nationally Determined Contributions to the Paris Agreement, such support efforts coalesce around the development of climate and weather monitoring, associated early warning early action measures, and climate change adaptation measures and approaches (such as climate-smart agricultural practices that will vary according the farming system). Policymakers are keen to maximise activities with mitigation and adaptation potential where possible which will be important when considering the region's limited, but important forest systems. With a better understanding of the impact of climate change on food security, countries will be able to mainstream climate-related programs and actions in their national development strategies and plans.

Analysis at the aggregate level will enable policymakers to anticipate where agricultural investments may no longer be financially viable and how they might redirect resources to minimise economic losses. Following such assessments, governments will be better placed to project their management of food imports, which is already of importance since NENA is currently one of the most food-import dependent regions in the world. This dependence has been rising over the past half-century, with many countries exceeding 50 percent food imports. Dependency makes the food supply to these countries vulnerable to the impacts that climate change will have on production in other parts of the world and the consequences this will have on international food prices. The countries for whom these imports are more expensive will need to consider the implications. Such market fluctuations could impact their ability to afford food imports. Some governments in the region are already anticipating this challenge.

Rising import costs could potentially have related trade implications. For instance, some of the oil and gas producing countries in the region have more favourable trading agreements and better opportunities to import food and virtual water. However, as climate change regulation (mostly in the form of policies implemented in association with the Paris Agreement) facilitates the transition away from fossil fuel-based energy, countries will need to consider how they diversify their income and the implications this will have for their international trade to ensure that their assets do not prematurely lose value. Effective management of these resources will require cross-sectoral integration to enhance the water, food and energy nexus. In conclusion, the actions taken to support small-scale farmers in the context of climate change has wide-ranging implications and needs to be considered alongside other national policies to ensure sustainable livelihoods and food security.

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Achieving the Sustainable Development Goals of eradicating poverty (SDG 1), hunger (SDG 2) and clean water and sanitation (SDG 6) is not possible without directly addressing the impacts of climate change (SDG 13). Agriculture and food systems are on the forefront of this challenge and nowhere is this more evident than in the Near East and North Africa (NENA) region. Climate change is projected to increase temperatures and extreme weather events and reduce precipitation and weather predictability. While there will be variations based on local specificity, this will result in a general reduction of the production and productivity of both crops and livestock throughout the farming systems in the NENA region. Small-scale farmers' livelihoods are at risk due to their direct dependence on natural resources. Further, given that they are the main domestic agricultural producers, the impacts of climate change on these farmers extends beyond the farm to the food security of the region. This makes it even more important for policymakers to determine the most effective ways to support small-scale farmers to ensure that agricultural production and productivity can be managed under changing climate conditions and increasing uncertainty.

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