CLIMATE CHANGE IMPACTS ON FOREST FIRES IN IRAN

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Behzad Farzipour

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1. Introduction

Forest fire activity is strongly influenced by climatic conditions that are changing as a result of anthropogenic activities. Studies suggest that climate changes are increasing the number of fire incidents in the world. Wide spread fires lead to degradation of land and destruction of ecosystems in forests. Iran is the home to some of rarest animal and plant species in ecosystems that are under constant threat of destruction due to fires. For instance, Golestan National Park on the coast of the Caspian sea which contributes to only 0.06% of Iran's total area, is the home to more than 1300 plants species and 20 of these cannot be found anywhere else in the world (ISDLE online).

This study is conducted to examine how global changes will impact climate in Iran, and how this in turn will impact the fire situation in the country. Moreover, distribution of fires and impacts of natural and human factors on spread of forest fires are investigated on a local scale. The study then discusses how forest fires could potentially impact the environment. Conclusion is preceded by preventive measures and future plans to decrease the growth rate of annual forest fires.

2. Forests, Fires, and Climate Change

2.1. Land Distribution and Changing Trends

In order to study forest fires, it is essential to be familiarized with area cover of forests, woodlands, and their changes during the past few years in Iran. To fully understand the data, definitions of “forest” and “woodland” are presented below, extracted from FAO (FAO/UN, Country Report: Iran, 2010):

“Forests are those lands spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more 10%, or trees able to reach these thresholds in situ. It does not include agriculture or urban land.”

“Other wooded lands are those not classified as forest, spanning more that 0.5 ha and with trees higher than 5 m and a canopy cover of 5-10%, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes, and trees above 10%. It does not include agriculture or urban land.”

Approximately 7% of Iran area is covered with forests with an index of 0.2 ha per capita (FAOSTAT, 2008). Iran has a widespread conservation network including seven national parks and around 60 other protected regions. Around 60%of Iran’s total area is arid desert or semi-desert (Allard, 2003).

According to the Forestry Department of the FAO/UN (2010), Iran has a forest area of 13.86 million ha, of which 11.1 million ha is covered with crown canopy cover of more 10% (listed above Third Class 1 according to FAO categorization of forested areas). The remaining areas include 2.6 million ha of shrubland and 0.08 million ha of parks and green spaces. Iran’s most valuable forests are located on the coast of the Caspian Sea and on the northern domain of the Alborz mountain range, with a total area of 1.85 million ha. The Zagros range in the west also has significant areas of forest, though much of the Zagros has been converted to grazing land (FAO, Forests and the Forestry Sector of Iran, 2010).
FAO has differentiated Iran’s forested areas as “North Forest” located on the coast of Caspian Sea and the northern domain of Alborz mountains; “Out of North Forests” mostly referring to those located on the domains of Zagros mountains in the west and the south-west of the country; and “Planted Forest” throughout the country. The breakdown of area for each of these categories with area more than 10% tree coverage is illustrated in Table 1 (FAO/UN, Country Report: Iran, 2010).

<table>
<thead>
<tr>
<th>Type of Forest</th>
<th>Area (1000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out of North Forest</td>
<td>8636.046</td>
</tr>
<tr>
<td>North Forest</td>
<td>1847.886</td>
</tr>
<tr>
<td>Planted Forest</td>
<td>592.922</td>
</tr>
<tr>
<td>Total</td>
<td>11074.554</td>
</tr>
</tbody>
</table>

FAO’s data is based on 1990 reports and has not been updated since.

According to the Environment Protection Agency of Iran, there has been a 22% reduction of forested land in the country during the past three decades, an equivalent of 0.7% annually on average (RadioFarda^1 online). For instance, according to satellite images there has been a 96,000 ha of reduction in the extent of Zagros forests during the past three decades. Although it is not clear that what has been the major cause of this reduction, but nearly 90% of these regions have been turned into agriculture land. Annual data illustrate a reduced rate of increase of this trend during the past decade (Khabaronline^1 online).

According to FAO, during the 25 years period starting from 1975, plantation of forests in irrigated and non-irrigated regions was established as a plan to protect the environment as well as supplying timber for local demand. An area of 0.25 million ha was planted during the period 1989-1992. By 1994, it was unofficially estimated that there were more than 0.47 million ha of plantations. By 2000 the total planted area in Iran reached 2.2 million ha. The government of Iran provides free seedlings to landowners to promote tree planting (FAO, Planted Forests of Iran, 2010).

2.2. Past Fire Situation
Annual data on forest fires are recorded for each province that indicate the number of incidents as well as the total area affected. Provincial data are collected by the Office of Protection and Environment. The data collection system in Iran requires serious improvements in order to meet international standards. According to the ECE/FAO database, during 1982-1995 on average there were 130 fire incidents in forests and other wooded areas that lead to 5,400 ha of land being burnt annually, giving a total of 33,000 ha during this period (Movaghati, 2008). Goldammer (2006) represents data from “Global Fire Monitoring Center”. Data available from this center reports FAO results for the 1998-2002 period, with an average loss of 6,500 ha of forest land annually due to fires (Goldammer, 2006).

From these result we may assume a 6,000 ha loss of forested land annually due to fires for 1982-2002. However poor monitoring and recording mechanisms as well as inadequate detection systems during this period puts the accuracy of data under question. Whatever the real numbers, these quantitative
data give the minimum losses of land recorded during these years due to forest fires. As will be discussed shortly, the total annual loss of forests may be orders of magnitude greater.

Official and non-official reports indicate that extensive areas of forests have experienced fires during the past year. The critical situation in the past year indicates a 100% increase in the number of incidents compared to the preceding year, with an unknown amount of total loss of forested lands (PHCE1 online).

Some reports indicate a total burnt area of 35,000 ha of forests in the western regions of the country alone during the past year (ILNA online), while other reports claim that the total area of about 40,000 ha was turned into ash during the past year throughout the country; this is eight times more than the preceding year (Darvish100 online). These numbers indicate a substantial increase in loss of forests compared to FAO 2005 reports. The accuracy of these numbers may be under question, but there is no doubt that the past year was the most disastrous year of forest fires and loss of forested land in the past century for Iran.

2.3. Overview on Climate Change and Forest Fires

Globally, the climate has experienced a warming induced by the radiative forcing of greenhouse gases in the atmosphere as a result of anthropogenic activities (IPCC 2001). This warming leads to some climatic changes that could potentially impact forest fire activities. Higher temperatures have known to be the most influential predictor of burned forests. Under a warmer climate, more severe fire weather, increased burned area, and a longer fire season is expected. However these are greatly dependent on the local conditions. Forest is also known to be highly dependent on human activities. Forest function, structure, and vegetation composition of any region is primarily influenced by forest fires (Flannigan, Amiro, Logan, Stocks, & Wotton, 2005).

Some studies (Including IPCC report) suggest global increases in frequency of fire incidents with increasing temperatures, though higher temperatures alone do no translate into greater fire disturbance since an individual fire is affected by ignition agents, humidity, wind velocity, and precipitation on a local scale (Flannigan, Stocks, & Wotton, 2000).

In order to stimulate current and future climate conditions, researchers employ General Circulation Models (GCMs) to gain insight into some of the changes. These models represent 3-D physical processes of atmosphere, oceans, and land surface, allowing the examination of rate of changes in climate. Despite the uncertainties involved—including radiative forcing of clouds, ocean response, and hydrological balance of land surface—GCMs, to a great extent, are capable of estimating the impact of climate change on forest fire regimes in the future.

With high confidence, most of the future projections from the results of these models suggest the highest temperature rise at high latitudes in winter. The climatic changes will also alter the precipitation, atmospheric moisture, and wind patterns. Extreme weather events could become more frequent resulting in occurrence of more large fires (Flannigan, Amiro, Logan, Stocks, & Wotton, 2005).
2.4. Projection of Forest Fire Situation

Iran is among the most vulnerable regions in the world to climatic changes, according to New Scientist based on an analysis of “Climate Change Vulnerability Index” produced by Maplecroft, a British risk analysis firm. As it is demonstrated in Figure.1, northern and western parts of the country, i.e. regions with highest density of forested lands, are under greatest risk compared to other regions (New Scientist, 2010).

Figure.1 The study looked at a range of risk factors including a nation’s exposure to climate-related disasters; its population density, poverty and dependence on agriculture; and its government’s and infrastructure’s ability to adapt to climate change (New Scientist, 2010).

IPCC projections for surface temperature changes relative to the period 1980–1999 indicate 1-2°C temperature rise for Iran under different scenarios for 2020-2029. For 2090-2099, Iran experiences varying temperature increases according to each scenario. These trends have been presented in Appendix.A.

IPCC projections for precipitation suggest that Iran will likely experience decrease in precipitation both in summer and winter. This is explainable since Iran is located on the desert belt of the northern hemisphere. The map for precipitation projections is presented in Appendix.B.

From these two projections it is expected that in Iran, forests become more prone to fires and accordingly, more area will be lost annually. With the past trends of fire incidents in forested lands
presented before in previous sections, there may be 300-400% rise of forest loss this year compared to the past year, according to the commander of Forest Guard Unit. According to Iranian scientists, with current rate and excess of forest fires, there will be no green space left in Iran by 2060 (Khabaronline\(^2\) online). Indications from historical area burned would suggest that the rate of change in area burned would not be linear and thus these projections of future trends cannot be reliable unless a precise monitoring scheme is conducted to produce chronological data for an adequate period of time.

A study conducted in 1991 comparing seasonal fire severity rating values\(^1\) for CO\(_2\) doubling scenario suggested 50% increase of forest area burned in Canada. The results of another study conducted in 2005 that quantified potential changes in future area burned due to climate change suggest an increase of 74–118% in area burned by 2100 in Canada (Flannigan, Amiro, Logan, Stocks, & Wotton, 2005). Iran will probably experience a less dramatic loss of forests because boreal forests are the most affected by climate change. However precipitation changes in Iran will considerably decrease, whereas boreal forest regions will experience likely increases in the amount of precipitation.

3. What Causes Fire and its Spread?
Many factors lead to growth of forest fires, but fires are mostly influenced by uncontrolled climatic changes and progressive warming of the globe, as well as human activities. This section examines physical and human factors that are the major causes of fires in Iran.

3.1. Physical Factors
Climatic conditions are the driving factor for increasing number of fire incidents in Iran. Extreme weather conditions have severe impact on northern forests of Iran. Extremely high temperatures, decreased precipitation, seasonal winds, and human activities are the most important factors for causing fires in Iran’s forested regions (KhabarOnline\(^2\) online). Drought conditions can make forests very sensitive to even high temperatures. Because of drought in some areas even a small leaf on fire can be transported by the wind and ignite fire in a forest. Moreover, windy conditions can make the quenching the fire very difficult and can spread the fire.

Precipitation is a factor that could have both negative and positive effects on forest fire. One of the most required acts of nature to suppress fires is rainfall. Since most fire incidents occur during dry seasons of the year, precipitation plays a minor role in controlling and quenching of fires. Paradoxically, adequate precipitation for growth of weed followed by dry conditions is a driving factor in the growth of fires. For instance, in Khouzestan province (which experiences mild winters with extremely high temperatures and dry conditions in summer), precipitation in winter leads to growth of weeds in forested areas, but summer conditions cause drying of these plants and make them even sensitive to the sun rays (Mehrnews\(^1\) online). Dramatic reductions of precipitation during autumn and winter in northern parts of Iran lead to increased probability of forest fires in these seasons and enhanced difficulties in suppressing

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\(^1\) Seasonal Severity Rating – a rating index to provide a measure of fire control difficulty and is a component of the Canadian Forest Fire Weather Index System

\(^2\) Khabaronline – a news website in Iran
them. Some parts of northern forests do not experience rainfall for more than 50 days during autumn (Jamejamonline online).

### 3.2. Human Factors

Allard (2003) claims that the causes of fire are different for each province, and although there is no database available on the cause if fire in Iran, she considers the following as the major causes of fire, but offers no further explanation of them:

- Land-use change (vegetation conversion)
- Conflict and resulting arson
- Carelessness of hunters and picnickers
- Landmines
- Smuggling of opium and oil through Iran
- Refugee activity

An increasing number of fire incidents since 2007 in some areas such as Kordestan has been partly due to deliberate human ignitions. As a new phenomena, squirrel trafficking alone has led to loss of tens of thousands hectares of oak forests in Kordestan on the western side of Zagros Mountains during the past few years (Mehrnews\(^2\) online).

Oak forests in western parts of Zagros domain are home to squirrels. These animals play a major role in natural reproduction of oak forests by burying oaks under soil. But increasing interest in keeping squirrels as pets is becoming a major cause of problem for both squirrels and oak forests as their living ecosystem. Squirrels prefer the old and high trees to those short trees with a big canopy. Animal traffickers ignite fires in oak forests to force these animals to leave the forest. They ignite these fires beneath old trees and make squirrels jump from tree into pre-set traps. Catching these animals for sale interrupts the natural cycle of reproduction of oak trees, as well as loss of oak forests due to fire and extinction of these animals in these areas. There has been a trend by many individuals to buy these animals in cities and return them to their natural homes (TabiatBakhtiari\(^1\) online).

Re-plantation of farmlands, especially for wheat, more than once a year is becoming a common practice in some areas of Iran. This requires the complete removal of crops left from the preceding harvest. In order to do this some, farmers ignite fires on the farmland that as a result of windy conditions can spread to neighbouring forests. This is an extremely dangerous practice, since the appropriate time for carrying it out this action is August and September, under dry conditions.

Extent of fire damage to forests is dependent on the following human factors:

- Delay in informing about a fire incident
- Late arrival of forces responsible for fire suppression
- Inadequate knowledge of locals about fire quenching

Inappropriate behaviour of tourists with nature in holiday seasons (i.e. mostly summer) has also been the cause of various fire incidents.
One of the most important limiting factors in quenching forest fires in Iran is the difficulty in accessing lands on fire. This is a major consideration when dealing with fires on the very steep domain of Zagros mountains. Moreover, lack of quenching equipment makes the fire control very inefficient; on so many occasions locals with shovels are doing the job of quenching before the arrival of other units. Poor crisis management is another important factor in the spread of forest fires in Iran, according to H. Arabzadeh, an environmental scientist in California (Radiofarda2 online).

4. Effects on Environment and Human

In the short term, smoke can cause positive feedbacks on weather and fire regimes by reducing local precipitation. On a global scale, carbon losses have the potential to create a positive feedback, whereby a warmer and drier climate will create conditions such that forests are more prone to fire. This in turn will increase carbon emissions from forest fires, which would enhance the warming (Flannigan, Amiro, Logan, Stocks, & Wotton, 2005).

How will the more severe fire situation impact the ecosystems? The fire regime has six components (Flannigan, Stocks, & Wotton, 2000):

- Frequency
- Size
- Intensity
- Seasonality
- Type
- Severity

Fire frequency interrupts or even terminates life cycles of organisms and species in an ecosystem. Fire size determines the distance that a seed has to travel for regeneration and also specifies fragmentation of landscape.

Fire intensity is essentially the amount of energy that is released during a fire incident by the flaming front of a fire. It is highly dependent on forest characteristics and thus the impacts of climate change on fire intensity may be a secondary effect. Fire intensity is important for two reasons (Flannigan, Amiro, Logan, Stocks, & Wotton, 2005):

- Fire intensity determines the fire suppression strategies required. For highly intense fires it will not be safe to place fire crews on the fireline and thus aerial attack is required.
- Mortality of vegetation in a fire incident can be determined by intensity of the fire.

The season of the year in which fire incident occurs partially determines the successional trajectories on which ecosystems embark after fire. Time of year may impact intensity of fire by changing the amount of moisture in surface and crown of forest. Fire type is strongly controlled by fire intensity and is categorized as crown, surface and ground fires. Fire severity is a measure of the damage in surface soil
organic layers and thus is an important factor controlling the function and structure of ecosystems after fire incident through affecting underground plant root and reproductive tissues.

It is apparent that altered fire regimes that are a result of climatic changes can have substantial impacts on ecosystems.

Available data illustrate that Iran is losing a large part of its forested land each year. This will severely affect ecosystems and their inhabitants, as well as those living close to forested lands. There are no data available on the annual emission of carbon to the atmosphere due to losses of forested land in Iran.

Many plant species, especially in northern forests, have already become extinct or are on the verge of extinction. Fire in this area and other remote areas that are home to some of the rarest plant species in the world is a big threat to these plants. As has been pointed out before, Golestan National Park in the north is the most vulnerable in this regard. Animal species also suffer from threat of extinction. In some areas, forest fires have forced animals to migrate to areas less appropriate for them to live.

The impact of uncontrolled fires can be very serious. Due to both human activities and climatic conditions, previously good forests are now degraded. Some areas are now deserts and the forest area is much reduced. Land management issues include unlimited grazing by cattle that causes damage to pastures and natural regeneration in forests (the main source of reforestation), conversion of forested land to agriculture, as well as cutting trees illegally and overlogging.

Impacts of climate change on forest fires can have strong implications for forestry management and community protection. Under a warmer climate, fires have a better chance to escape the initial attack of fire management agencies, resulting in a greater damage to forest and greater losses of land. This relationship could also potentially influence the direct effects of climate change and global warming on migration and distribution of plant species (Flannigan, Amiro, Logan, Stocks, & Wotton, 2005). Few human mortality is directly attributed to forest fires.

5. Geographical and Seasonal Distribution of Fires
Climatic conditions and location are important factors affecting distribution of fires. Northern forests mostly experience fire from August to December when there are windy conditions with decreased humidity (e.g. Golestan province). On the domains of Zagros in western parts of the country conditions in summer and winter make forests more prone to fire (e.g. Kordestan province). During the period from March until September central and southern parts of Iran can suffer from forest fires due to extremely high temperatures and drought (e.g. Khouzestan province). There are some occasional transboundary fires along the borders with Iraq and Turkmenistan that are difficult to access and control (Allard, 2003).

Kordestan (western Iran) has 0.37 million ha of forested land and 1.4 million ha grazing land and thus has a very important status in Iran’s environment (30mail2 online). Because of climatic conditions in this region, forested regions in Kordestan are under constant threat of fire. This province experiences extremely cold winters followed by dry summers that is prone to fire under windy conditions. The
province experienced more than 1000 fire incident in 2010 that were mainly due to drought, high temperatures, and human ignitions, according to head of Kordestan Natural Resources (30mail² online).

Golestan (north east Iran) is the most important forest area of Iran on the coast of the Caspian Sea. Golestan is home to some of the rarest animal and plant species. There are 20 plant species in Golestan National Park that cannot be found anywhere else in the world. Moreover, Persian leopard, one of the most distinct leopard breeds in the world lives in northern forests of Golestan. Fires in Golestan are a threat to more than 430,000 ha of forests. Although the fires are small initially, but because of steep areas in protected lands, access is very difficult and therefore fire is hard to control (30mail³ online). In November 2010 more than 80 incidents were reported in Golestan and 70 protected areas of forests experienced fire (PHCE¹ online). Extremely dry conditions experienced this year were a major cause of widespread fires (MehrNews⁴ online).

Khouzestan (south west Iran) experiences wild winters and extremely high temperatures in summer. Drought is a common phenomenon in this region. Desert winds entering from Iraq on the west are one of the most influential causes of fire spread in the region.

6. Preventive Actions and Response Methods

The Forest Guard Unit was established in 2005 and is obliged to safeguard forests, provide regular patrol and surveillance, and take any preventive actions to protect, fight, and control any types of fires in natural resources and forests (UNFF, 2010). Government of Iran has designated $800m annual budget for the protection of forests from fire. According to the “Comprehensive Plan for Prevention and Suppression of Forest Fires” under the supervision of Interior Ministry, this budget must be spent to fully equip all the forested lands with helicopters, hardwares for fire quenching, and softwares for fire detection. But commander of the Forest Guard Unit claims that this budget was not fully provided to organizations dealing with forest fires for the past few years (KhabarOnline³ online). Deputy of Crisis Management Organization of Iran has promised to equip all forested lands with fire detection sensors that are sensitive to high temperatures. He also mentioned that this organization will be supported by the Ministry of Defence by providing ultralight planes that are equipped with water containers for the time of incident (MehrNews⁴ online).

Prevention is considered as being cost-effective; thus local communities are involved in preventive actions. Industrial husbandry is substituting traditional husbandry through renovation projects with an emphasis on forbidding grazing. In these regions, grazing is being prohibited to enhance forest reproduction and to prevent fires.

Some of the preventive measures that have been carried out in Golestan are a 156 km of green strips that have been planted in forests and 936 ha of protection channels with depth of 1 m that have been dug between the farms and forest serving as fire breaks (Allard, 2003).

Education through mass media for public and through primary schools for youth can be a deciding factor for fire suppression. Public awareness campaigns include brochures, TV, radio. Specific information is
provided during the fire season through the use of fire risk signposts. In some provinces all members of
the community, including hunters, are trained in fire prevention (Allard, 2003). For instance digging
creeks branching from main water streams and rivers in the time of an incident is one of the actions that
have been taught to locals (Mehrnews¹ online). In Kordestan province, $100,000 has been designated on
education and cultivation of villagers for forest and grazing land protection (Mehrnews⁵ online). Inadequate knowledge of locals about fire quenching can lead to reduced motivation for suppressing
fire (TabiatBakhtiari² online).

7. Future Plans
Forests, Rangelands and Watershed Management Organization (FRWO) is the leading governmental
institution for regeneration, restoration, and plantation of degraded forest lands. Below are a summary
of their past and future plans (UNFF, 2010):

- Promote regeneration and restoration of degraded forest regions
  - Afforestation and Green Spaces Development: until 2008, FRWO had approximately
carried out 0.92 million ha of conservation projects for afforestation in the forests on
coast of the Caspian Sea. It has also considered plantation of 1.8 million ha of new
forests in arid and semi-arid regions.
  - Restoration of Degraded Forests: This program started in 2002 and has been carried out
in different parts of the country under arid and semi-arid climatic conditions for
reclamation of 12.3 million ha of degraded forests.

- Promotion of natural and planted forests
  - National Program on Conservation and Development of the Northern Forests: From
1797 till 2008, FRWO had approximately carried out some 0.43 million ha of new
plantations in the Caspian region. The Natural Resources and Watershed Management
Vision has designated the rehabilitation of 0.4 million ha of degraded forests as well as
plantation of 0.2 million ha of new forests by 2025 in the region.
  - National Programs on Conservation and Development of the Zagros and Southern
Forests: The Natural Resources and Watershed Management Vision has envisaged the
rehabilitation of 1.4 million ha of degraded forests as well as plantation of 8.3 million ha
of new forests in these regions. Forests in these areas were degraded due to excessive
logging, soil infertility and over-grazing. The main activities under this program are
reclamation and regeneration activities (including fencing, seeding and seedling),
reduction of degradation factors (including forest fires and illegal cuttings), and
formulation of multipurpose forestry plans.
8. Conclusion

Global trends suggest severe fire situations as a result of climatic changes. On a local scale, although much uncertainty is involved, Iran is projected to experience critical situations of forest fires in the coming years. This will substantially impact forest ecosystems and pushes many plant species towards extinction. It can also cause migration or extinction of animal species.

Lack of reliable chronological data is caused by poor monitoring of fire incidents and land losses. Even at present time, forest fires are not properly monitored. Fire management programmes including prevention and suppression can greatly impact fire activities. Preventive measures and actions can only be effective if monitoring techniques are greatly improved in Iran. Impacts of a changing climate on fire regimes may be dampen or amplified according to the effectiveness of fire management policies.

The current critical fire situation in Iran should encourage the development of plans and options to mitigate or adapt to the potential changes.
Climate Change Impacts on Forest Fires In Iran

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-Tabiat Bakhtiar:
Notes: Figure shows projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the AOGCM multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020–2029 (centre) and 2090–2099 (right). The left panels show corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and Earth System Model of Intermediate Complexity studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves shown in the left-hand panels is due only to differences in the availability of results.

*Climate Change 2007: Working Group I: The Physical Science Basis*

Appendix B

June–July–August (JJA)

December–January–February (DJF)

Based on regional studies assessed in chapter 11:
- Precipitation increase in ≥90% of simulations
- Precipitation decrease – very likely
- Precipitation extreme increase – likely
- Precipitation increase – likely
- Increased drought – likely
- Less snow – very likely
Notes: Figure shows Robust findings on regional climate change for mean and extreme precipitation, drought, and snow. This regional assessment is based upon AOGCM based studies, Regional Climate Models, statistical downscaling and process understanding. The background map indicates the degree of consistency between AR4 AOGCM simulations (21 simulations used) in the direction of simulated precipitation change.

*Climate Change 2007: Working Group I: The Physical Science Basis*