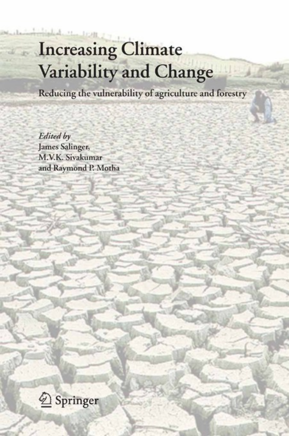

Increasing Climate Variability and Change

Reducing the vulnerability of agriculture and forestry

Edited by
James Salinger,
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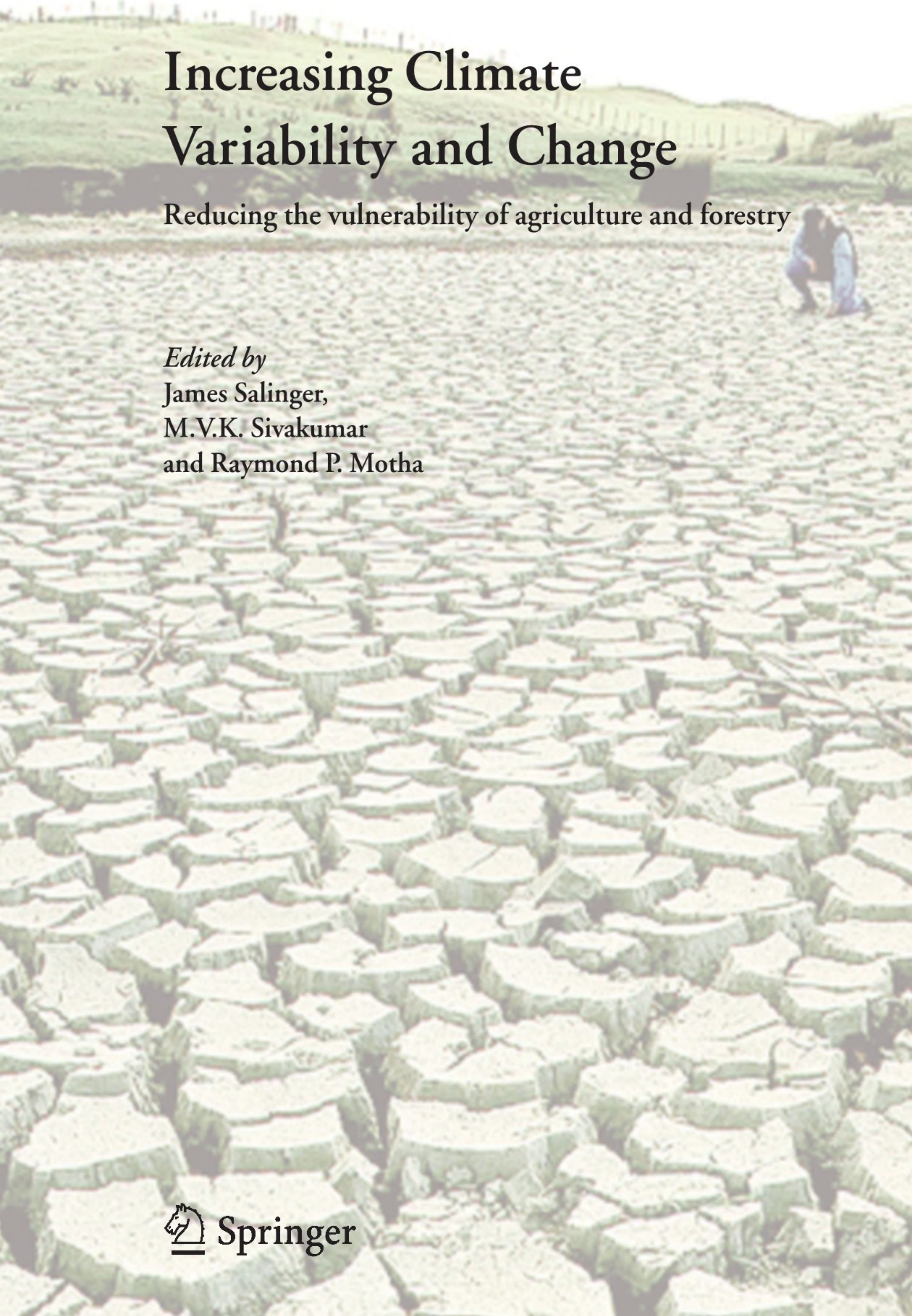

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INCREASING CLIMATE VARIABILITY AND CHANGE: REDUCING THE VULNERABILITY

Guest Editorial

Since time immemorial, climate variability and change have triggered natural disasters and climate extremes causing heavy losses of life and property, forcing civil society to "learn to live" with these calamities. Floods, droughts, hurricanes, storm surges, heat waves precipitating wild fires and such other natural calamities have claimed more than 2.8 million lives all over the world in the past 25 years, adversely affecting 828 million people. Damage caused by these climate extremes during the same period was estimated at 25–100 billion dollars, dramatically affecting agriculture and forestry systems in regions where these have occurred.

Agricultural and forestry production is highly dependent on climate, and is adversely affected by increasing climate variability and anthropogenic climate change leading to increases in climate extremes. There is strong evidence that global warming over the last millennium has already resulted in increased global average annual temperature and changes in rainfall, with the 1990s being likely the warmest decade in the Northern Hemisphere at least. During the past century, changes in temperature patterns have, for example, had a direct impact on the number of frost days and the length of growing seasons with significant implications for agriculture and forestry. Land cover changes, changes in global ocean circulation and sea surface temperature patterns, and changes in the composition of the global atmosphere are leading to changes in rainfall. These changes may be more pronounced in the Tropics.

During the course of the 21st century, scientific evidence points to global-average surface temperatures are likely increasing by 2–4.5 °C as greenhouse gas concentrations in the atmosphere increase. At the same time there will be changes in precipitation, and climate extremes such as hot days, heavy rainfall and drought are expected to increase in many areas. The combination of global warming will be superimposed on decadal climate variability, such as that caused by the Interdecadal or Pacific Decadal Oscillation, and interannual fluctuations caused by the El Niño/Southern Oscillation and the North Atlantic Oscillation. All these may lead to a century of increasing climate variability and change that are expected to be unprecedented in the history of human settlement and agrarian activities.

The main purpose of the United Nations Framework Convention on Climate Change (UNFCCC, 1992) is to reduce the growth of greenhouse gases. Article 2 of the Convention states that its ultimate objective is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

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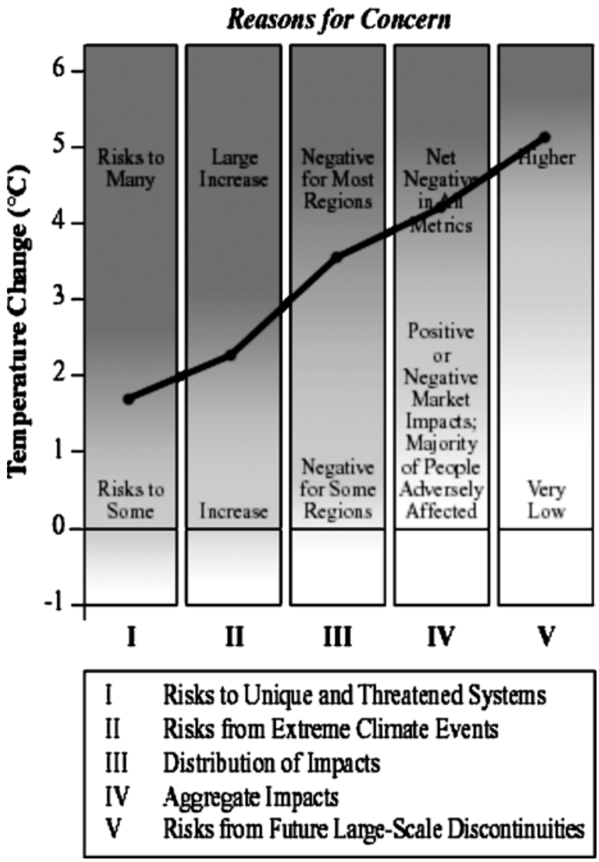

Figure 1. The risk of adverse impacts increase with the magnitude of climate change. Global mean annual temperature is used as a proxy for the magnitude of climate change (IPCC WG2, as modified by Mastrandrea and Schneider, 2004).

The natural greenhouse effect keeps the planet and biosphere at an equable temperature for planetary processes to operate. The current rate of global warming is 2 °C per century, and this rate is projected as a lower range for the remainder of the 21st century. Thus, increases in greenhouse gases released by human activities are creating a potential situation where the stability of agriculture and forestry systems is threatened by dangerous climate change (Figure 1).

Adapting to increasing climate variability then provides tools to reduce the vulnerability of agriculture and forestry. Some farming systems with an inherent resilience may adapt more readily to climate pressures, making long-term adjustments to varying and changing conditions. Other systems will need interventions for adaptation. Traditional knowledge and indigenous technologies should not be ignored. Age-old technologies such as planting calendars, intercropping and mulching reduce the vulnerability to climate extremes.

However, the path of increasing variability and change will require the introduction of much more sophisticated technologies. Seasonal to interannual climate forecasting is a relatively new branch of climate science, and it promises reducing vulnerability. Improved seasonal forecasts are now being linked to decision making for cropping, developing climate risk practices to improve the application of climate information for the management of grazing practices, and developing climate risk practices to enhance the productivity and performance of forests. The application of climate knowledge to the improvement of risk management will increase the resilience of farming systems.

Consequently, the occurrence of seasonal to interannual climate variability and their extremes can be forecast with a greater degree of accuracy. Availability of such crucial information in advance can greatly assist in taking effective measures for prevention and mitigation of losses by agricultural and forestry. Thus, the resultant disastrous effect can be reduced considerably through proper planning and more effective preparedness. Vulnerability associated with climate can be controlled to some extent by accurate and timely prediction and by taking counter-measures to reduce their impacts on various sectors of agriculture.

One fact is for certain though – the historical record shows that our climate has changed in the past, and will continue to vary and change during the coming seasons and decades. The underlying theme of global warming is likely to cause increases in temperature and their extremes of heat waves, with climate scenarios of changing rainfall patterns as the 21st century progresses, with increasing extremes of floods and droughts. These will provide a challenge unparalleled in the history of civil society to agriculture and forestry: the papers in the this issue of *Climatic Change* assess the likely impacts of change and examine the adaptation and capacity building options to reduce vulnerability and increase resilience.

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FOREWORD

One of the major challenges facing humankind is to provide an equitable standard of living for the current and future generations: adequate food, water and energy, safety, shelter and a healthy environment. Human-induced climate change, and increasing climate variability, as well as other global environmental issues such as land degradation, loss of biological diversity, increasing pollution of the atmosphere and fresh water and stratospheric ozone depletion, threaten our ability to meet these basic human needs. Considerable efforts have been deployed in monitoring and projecting the changes and in evolving possible options for managed systems including agriculture and forestry.

Today, there is certainty from the surface temperature data, collected by WMO's Global Observing System, that the globally averaged surface temperatures are rising. According to records maintained by members of WMO, the global surface temperature has increased since the beginning of instrumental records in 1861. Over the 20th century that increase was about 0.6 °C. The rate of change for the period since 1976 is roughly three times that of the past 100 years. Analyses of proxy data for the Northern Hemisphere indicate that the late 20th century warmth is unprecedented for at least the past millennium. Over the same period, the 1990s were the warmest decade, the year 1998 was the warmest year and the years 2002 and 2003 the second and third warmest, respectively. The projected temperature rise by the end of the century is between 1.4 and 5.8 °C.

Scientific assessments have shown that over the past several decades, human activities, especially burning of fossil fuels for energy production and transportation, are changing the natural composition of the atmosphere. Proxy records indicate that for over at least the last 400,000 years, up to about 1800 AD, the atmospheric concentration of carbon dioxide (CO_2) varied only by 1–3 per cent. Since then, it has increased by more than 33 per cent, and reached 376 parts per million by volume (ppmv) at the end of 2003. WMO's Global Atmosphere Watch observing network monitoring atmospheric chemistry show that today's atmospheric CO_2 concentration has not been exceeded during the past 420,000 years. More than half of that increase in CO_2 concentration has occurred since 1950.

It is also possible, even likely in some cases, that human-induced climate change will affect naturally occurring climate variability such as the frequency or intensity of El Niño/Southern Oscillation (ENSO) events. A growing number of extreme weather and climate events, some of which have been of unprecedented intensity, continue to be observed with associated degradation of the environment. This requires the global community to give urgent attention and high priority to addressing key issues related to climate change through appropriate measures and policies at national and regional levels.

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Climate variability affects all economic sectors, but agricultural and forestry sectors are perhaps two of the most vulnerable and sensitive activities to such climate fluctuations. Climate change and variability, drought and other climate-related extremes have a direct influence on the quantity and quality of agricultural production and in many cases, adversely affect it, especially in developing countries, where the pace of technology generation, innovation and adoption does not allow them to counteract the adverse effects of varying environmental conditions. For example, inappropriate management of agroecosystems, compounded by severe climatic events such as recurrent droughts in many parts of the world, have tended to make the drylands increasingly vulnerable and prone to rapid degradation and hence desertification. Even in the high rainfall areas, increased probability of extreme events can aggravate nutrient losses due to excessive runoff water logging. Projected climate change can influence pest and disease dynamics with subsequent crop losses. Improved adaptation of food production, particularly in areas where climate variability is large, holds the key to improving food security for the global population.

The range of adaptation options for managed systems such as agriculture and forestry is generally increasing because of technological advances, thus opening the way for reducing the vulnerability of these systems to climate change. However, some regions of the world, particularly developing countries, have limited access to these technologies and appropriate information on how to implement them. Here successful traditional technologies used over the centuries should be maintained. Incorporation of climate change concerns into resource-use and development decisions and plans for regularly scheduled investments in infrastructure will facilitate adaptation.

Agriculture and forestry are currently not optimally managed with respect to today's natural climate variability because of the nature of policies, practices and technologies currently in vogue. Decreasing the vulnerability of agriculture and forestry to natural climate variability through a more informed choice of policies, practices and technologies will, in many cases, reduce the long-term vulnerability of these systems to climate change. For example, the introduction of seasonal climate forecasts into management decisions can reduce the vulnerability of the agriculture to floods and droughts caused by the ENSO phenomena.

It is with this background that WMO had organized the International Workshop on Reducing Vulnerability of Agriculture and Forestry to Climate Variability and Climate Change in conjunction with the 13th session of the Commission for Agricultural Meteorology of WMO held in October 2002 in Ljubljana, Slovenia. The workshop was co-sponsored by the Asia-Pacific Network for Global Change Research (APN), the Canadian International Development Agency (CIDA), the Centre Technique de Coopération Agricole et Rurale – Technical Centre for Agricultural and Rural Co-operation (CTA), the Environmental Agency of the Republic of Slovenia, the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia, the Ministry of Environment, Spatial Planning and Energy of the Republic of Slovenia, the Food and Agriculture Organization of the United Nations (FAO), the Fondazione per la Meteorologia Applicata and the Laboratory for Meteorology & Climatology (F.M.A.-La.M.M.A.), Météo-France, the International START Secretariat (START), the Ufficio Centrale di Ecologia Agraria (UCEA), the United Nations Environment Programme (UNEP) and the United States Department of Agriculture (USDA).

The workshop reviewed the latest assessments of the science of climate variability and climate change, and their likely impacts on agriculture and forestry in different agroecological regions during the 21st century. It also surveyed and presented a range of adaptation options for agriculture and forestry and recommended appropriate adaptation strategies required to reduce vulnerability of agriculture and forestry to the observed and projected climate variability and climate change highlighted earlier. I hope that the papers presented in this special issue will serve as a major source of information to all services, agencies and organizations at national, regional and global levels involved with designing and implementing appropriate programmes in using agrometeorological techniques to reduce vulnerability to climate variability and climate change through the course of the 21st century.

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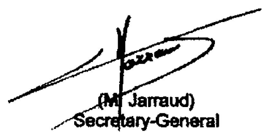

CLIMATE VARIABILITY AND CHANGE: PAST, PRESENT AND FUTURE – AN OVERVIEW

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Abstract. Prior to the 20th century Northern Hemisphere average surface air temperatures have varied in the order of 0.5 °C back to AD 1000. Various climate reconstructions indicate that slow cooling took place until the beginning of the 20th century. Subsequently, global-average surface air temperature increased by about 0.6 °C with the 1990s being the warmest decade on record. The pattern of warming has been greatest over mid-latitude northern continents in the latter part of the century. At the same time the frequency of air frosts has decreased over many land areas, and there has been a drying in the tropics and sub-tropics. The late 20th century changes have been attributed to global warming because of increases in atmospheric greenhouse gas concentrations due to human activities. Underneath these trends is that of decadal scale variability in the Pacific basin at least induced by the Interdecadal Pacific Oscillation (IPO), which causes decadal changes in climate averages. On interannnual timescales El Niño/Southern Oscillation (ENSO) causes much variability throughout many tropical and subtropical regions and some mid-latitude areas. The North Atlantic Oscillation (NAO) provides climate perturbations over Europe and northern Africa. During the course of the 21st century global-average surface temperatures are very likely to increase by 2 to 4.5 °C as greenhouse gas concentrations in the atmosphere increase. At the same time there will be changes in precipitation, and climate extremes such as hot days, heavy rainfall and drought are expected to increase in many areas. The combination of global warming, superimposed on decadal climate variability (IPO) and interannual fluctuations (ENSO, NAO) are expected lead to a century of increasing climate variability and change that will be unprecedented in the history of human settlement. Although the changes of the past and present have stressed food and fibre production at times, the 21st century changes will be extremely challenging to agriculture and forestry.

1. Introduction

In the course of climate history over the last millennium, there has been intense interest on the cooling documented to the 19th century for the Northern Hemisphere (NH) at least, the cooler period of climate in the 19th century and rapid global warming during the late 20th century. Over the last millennium climate has varied by as much as 1 °C globally (IPCC, 2001a). Key questions of any future impacts of global warming are the effects on human society and economics, and in particular, on agriculture and forestry. History can provide very valuable lessons on effects of climatic variability on the human dimensions. The multidecadal cooling of the late 16th century in Europe resulted in one of the peak cooling excursions of the so called Little Ice Age epoch of Europe. This example of climate variability provides impacts of a mere 0.5 °C cooling in annual mean temperature on society.

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Increases were observed in surface global temperatures during the 20th century, and interannual climate variability has been observed in many regions of the globe (Salinger, 1994; Salinger et al., 1997). The 1982/83 and 1997/98 El Niños and the 1991 Mt. Pinatubo volcanic eruption (Salinger et al., 2000) caused considerable variability in the interannual climate of tropical regions in the late 20th century. Recently IPCC (2001a) reported on warming trends, confirmation of continuing climate change based on observations from Arctic and Antarctic sea ice, from later ice appearance days and earlier ice breakup days particularly in European Russia, the Ukraine and Baltic countries. Observations of shrinking mountain glaciers during the 20th century and the increase of permafrost temperatures in many areas occurring provides additional confirmation.

Perhaps of more importance are the implications on agriculture that arise from the multidecadal climate fluctuations. If climatic variability in the order of 0.5 °C can cause such dramatic effects on glaciers, flood events and storm surges, agricultural commodity prices, wine yields and other societal effects as documented for the 16th century, then this poses questions of what are the impacts of the projected increasing climatic variability and change during the 21st century. There is now better understanding of the climate system, and the natural and anthropogenic factors that have caused climate variability and change over the past century, and likely changes in climate and its variability during the 21st century (Salinger, 1994; Salinger et al., 1997, 1999; IPCC, 1996, 2001a). The latest IPCC projections (IPCC, 2001a) from the entire range of 35 IPCC scenarios place temperature increases in the range of 1.4 to 5.8 °C by the end of the 21st century, with likely increases in heavy rainfall events. The 90% range is 2 to 4.5 °C.

Although agrometeorology provides methods and technologies to allow adaptation of food and fibre production to cope with increasing climate variability and climate change (Salinger et al., 2000) lessons from the past are that the consequences can only be dramatic. An overview of past climate trends over the last millennium is provided as a context to view current climate variability and future trends for providing increasing preparedness of agriculture and forestry to future variability and change. Climate trends during the 21st century from scenarios of human activities are described, together with broadscale implications for agriculture and forestry. The United Nations Framework Convention on Climate Change has clauses on 'Dangerous Climate Change'. This concept will be examined in terms of the ability of agriculture and forestry to adapt to anthropogenic climate change this century.

2. Past Climate

2.1. THE LAST THOUSAND YEARS

The course of annual average temperature change for the Northern Hemisphere over the past 1,000 yr is shown in Figure 1. This is a particularly important time frame

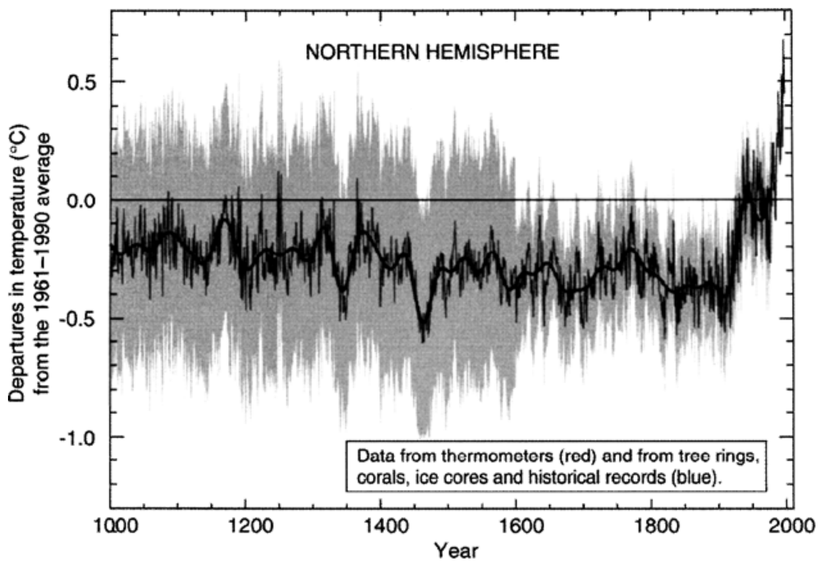

Figure 1. Northern Hemisphere average annual surface air temperature variations over the last millennium from proxy, historical and instrumental observations (IPCC, 2001a). Temperature reconstruction and instrumental data from AD 1000–1999. Smoother version of NH series and two standard error limits (gray shaded) are shown.

for assessing the background natural variability of climate, to place 21st century changes in context of which both modern and traditional agricultural and forestry systems developed over the past millennium.

Palaeoclimate proxy indicators (Folland et al., 2001) include tree rings, which provide precisely dated annual information, corals that provide information on past variability of the tropical and sub-tropical oceans and ice cores from polar regions of Greenland and Antarctica, which can have annual resolution. Other information can be gleaned from borehole measurements, which provide broadscale temperature trends, historical documentary evidence particularly from Europe and China, and mountain glacier moraines providing evidence of past glacial advances.

From these sources there is enough evidence to reconstruct temperature patterns over the Northern Hemisphere back to AD 1000 (Folland et al., 2001). These reconstructions show a slow cooling peaking around AD 1450 and 1880 over the last 1,000 yr, with the most recent cool period being around the end of the 19th century. Lamb (1982) has documented the downturn of climate in the North Atlantic/European region commencing with the storminess and cooling and wetness of 14th century Europe. Desertion of farms and village settlements are noted all over northern and central Europe. The prevailing wetness led to more prevalent disease. During the late 1500 s many years of general death and famine occurred in Scotland. For Norway extremely stormy years are noted in the 1600 s with changes in fisheries around Scandinavia.