Climate Change Impacts, Mitigation and Adaptation

Science for Generating Policy Options in Rajasthan, India

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Rajasthan State Pollution Control Board
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The Rajasthan State Pollution Control Board is a body corporate constituted under section 4 of the Water (Prevention and Control of Pollution) Act, 1974. It was first constituted on February 7, 1975, with the objectives of prevention, and control of water pollution and maintaining or restoring of wholesomeness of water. Later, it was also entrusted with the responsibilities of prevention, control and abatement of air pollution under the provisions of Air (Prevention and Control of Pollution) Act, 1981. Water (Prevention and Control of Pollution) Cess Act, 1977 has been enacted to make the State Board financially independent. Under this act the State Board has been given powers to collect cess on the basis of water consumed by the industries and others. Besides, the State Board is also implementing the provisions of the Public (Liability) Insurance Act, 1991. Enactment of the Environment (Protection) Act, 1986 has further widened the scope of the activities of the Board. This act being umbrella legislation, different rules for addressing the problems of various sectors have been enacted under this act. Currently, the State Board is engaged in implementation of the following rules under EPA, 1986:

- Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008.
- Manufacture, Storage & Import of Hazardous Chemical Rules, 1989.
- Public (Liability) Insurance Act, 1991.
- Environmental Impact Assessment (Aravali) Notification Dated 7.5.1992.
- Environmental Impact Assessment Notification dated 14.09.06.
- Bio Medical Waste (Management & Handling) Rules, 1998.
- Plastic Manufacture & Usage Rules, 1999.
- Noise (Pollution Control & Regulation) Rules, 2000.
- Municipal Solid Waste (Management & Handling) Rules, 2000.
- Batteries (Management & Handling) Rules, 2001.

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सत्यमेव जयते

CHIEF MINISTER
RAJASTHAN

Message

Climate change is the greatest challenge before the global society, impacting the ecology, economy and society in several ways. Changes related to the climate of Rajasthan are over and above the natural climate variability prevailing in this area. Studies have shown that Rajasthan falls within the areas of greatest climate sensitivity, maximum vulnerability and lowest adaptive capacity. As history informs us, Rajasthan also has the maximum probability of occurrence of drought in India. If various segments of our society fail to act timely and coherently, climate change is likely to affect every sphere, and may make livelihoods of poor people more vulnerable and less resilient.

We will, therefore, require scientific knowledge to identify and implement strategies for climate change mitigation and adaptation. Indeed, climate-proofing of ecological, economic and social infrastructure is definitely going to be a knowledge-intensive effort.

I am happy to note that a multi-disciplinary team of scientists and practitioners from Indian Institute of Science, Bengaluru, Indian Institute of Technology, Kharagpur, and Rajasthan State Pollution Control Board, Jaipur collaborated to explore the available scientific knowledge crucial for generating the implementable policy options in Rajasthan. I have been informed that this effort is the first of its kind for any State in India, and I commend the team for their scientific endeavour.

I hope the report will serve as a valuable source of ideas for policy-makers, practitioners and scientists striving to address the challenge of climate change through evidence-based policy and action.

(Ashok Gehlot)

Abbreviations and acronyms

^{14}C - carbon-14
AD - Anno Domini
C - carbon
cal years BP – calander years before present
CO_2 - carbon dioxide
ENSO - El Niño/Southern Oscillation
FAO - Food and Agriculture Organization
ha^{-1} - per hectare
ha^{-1} yr^{-1} - per hectare per year
Holocene - a geological epoch which began about 12,000 years ago
ka BP - thousand years before present
kg C/km^2 - kilogram carbon per square kilometer
km - kilomeres
kWh/m^2 /day - kilowatt hours per square meter per day
m^2 - square meter
m^3 - cubic meter
mcm -million cubic meters
Mg - megagram (10^6 grams)
mha - million hectare
Mt - Megaton (or 10^6 tons, or 1 Terragram)
MW - megawatt
Pg - petagram (10^{15} grams)
ppbv - parts per billion by volume (10^9)
ppmv - parts per million by volume (10^6)
t - Ton or tones
t ha^{-1} - tonnes per hectare
TGA - total geographical area
TgC - Teragrams of Carbon (or 10^{12} grams)
WHO - World Health Organization
$\delta^{13}C$ - a measure of the ratio of stable isotopes ^{13}C:^{12}C

1.
Introduction

Climate change is one of the greatest challenges of our time. Fossil-fuel burning and deforestation have emerged as principal anthropogenic sources of rising atmospheric carbon dioxide (CO_2) and other green-house gases and consequential global warming. Proxy records of variability in temperature, precipitation, sea level and extreme weather events provide collateral evidence of global climate change. Observational data from land and oceans as well as model results suggest that several ecological, economic and social systems are being affected by climate change.

Indeed, there is compelling, comprehensive, consistent, and objective evidence that humans are altering the climate in ways that threaten our societies and the ecosystems. Scientific understanding is now remarkably coherent on following fundamental conclusions about climate change[1]:

> (i) The planet Earth is warming due to increased concentrations of heat-trapping gases in atmosphere. Snowy winters in some parts of the world do not alter this fact.
>
> (ii) Most of the increase in the concentration of green-house gases over the last century is due to human activities, particularly the burning of fossil fuels and deforestation.
>
> (iii) Natural causes always play a role in changing Earth's climate, but are now being outcompeted by anthropogenic changes.
>
> (iv) Warming of the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle. Rising concentrations of carbon dioxide are making the oceans more acidic.
>
> (v) The combination of these complex climate changes threatens coastal communities, cities and rural systems, our food and water supplies, marine and freshwater ecosystems, forests, high mountain environments, and far more.

Rajasthan is the largest state in India with two-third of its area as Thar desert. The entire State receives scanty rainfall. Thar Desert in

western Rajasthan is characterized by low and erratic rainfall, high air and soil temperature, intense solar radiation and high wind velocity. Context-specific interactions of these factors not only give rise to frequent droughts and famines, they also make local livelihoods highly vulnerable.

On top of the above challenges, the State also falls within the areas of greatest climate sensitivity[2]. In an era of climate change, Rajasthan is likely to suffer further water shortage due to overall reduction in rainfall. In addition, the State has the maximum vulnerability and lowest adaptive capacity to climate change challenges. Rajasthan has the maximum probability of occurrence of drought in India[3]. Condition may deteriorate in terms of severity of droughts in Rajasthan. Even though 20% rise in all-India summer monsoon rainfall is projected, in Rajasthan overall rainfall is projected to decrease, and evapotranspiration to increase, due to global warming[4]. Even 1% increase in temperature from base data could result in an increase in evapotranspiration by 15 millimeter (mm), resulting into additional water requirement of 34.275 million cubic meter (mcm) for Jodhpur district alone and 313.12 mcm for entire arid zone of Rajasthan. Although analysis of 100-year rainfall data for the arid region of Rajasthan indicates an increasing trend of 0.5 mm/year, but increased evapotranspiration demand due to global warming can put tremendous pressure on existing overstressed water resources of this region.[5]. As the total available surface water resources of the arid zone are to the tune of 1361.21 mcm, a robust policy intervention is required for sustainable water management.

Studies have documented a rising trend in temperature at Barmer, Jodhpur, Ajmer and Pali in Luni river basin of arid western Rajasthan. In the same region, annual rainfall has shown increasing tendency at 19 stations (around Ajmer in upper part of the Luni basin). Decreasing temperature trends have been observed at Udaipur and Jwaibandh, and decreasing rainfall trend at the remaining nine stations in lower Luni basin, i.e., Barmer[6]. Overall, there is a prediction of an increase in the rainy day intensity by 1–4 mm/day in India, but some areas in the northwest India the rainfall intensities are predicted to decrease by 1 mm/day[7].

Widespread land degradation is a persistent challenge in Rajasthan[8]. Recent studies[9] have further predicted that due to climate change there may be significant increase in the desert area over India in next 100 years with potentially disproportionate impact of global warming on coupled human and natural systems. Model studies on the wind erosion potentials in the Thar region for AD 1951 to 2100 suggest

that larger efforts in land-conservation practices would be required than at present to stabilize the aeolian bedforms in the Thar desert[10].

Human societies have evolved through complex interactions of climate and environmental systems. There is an intimate relationship of climate fluctuations and consequent human responses such as migration, adaptation and mitigation[11]. Climate variability and oscillations, such as droughts and floods, have occurred in the past and may occur in future, potentially with large impacts on society, economy and ecosystems. Thus, even though future man-made global warming may come gradually, it may be interspersed with surprising changes in climate and monsoon such as severe droughts and furious floods.

Societal vulnerability to the risks associated with climate change may exacerbate ongoing social and economic challenges, particularly for poor rural people and societies dependent on natural resources that are sensitive to climate change. Indeed, risks of global warming and environmental changes are already clearly visible in agriculture, forestry, fisheries, water resources, tropical soils, flora and fauna and other components that constitute the livelihood of rural people in developing countries. Livelihoods may diminish due to reduced productivity of green revolution in developing countries under the influence of recurring droughts and floods.

Thus, society will require robust knowledge to pursue strategies for mitigation as well as adaptation in order to address the challenges associated with global warming and climate change. Accordingly, here we briefly review the available literature and provide an annotated bibliography of published research on climate change impacts, mitigation and adaptation in order to facilitate the identification of policy options in Rajasthan. We also include literature on how human societies contribute to environmental change and how, in turn, become vulnerable to these changes. We also explore the available knowledge on how likely ecosystem goods and services are impacted to climatic oscillations (*environmental sensitivity*) and the ability of rural communities to cope (*social resilience*) with those changes.

1.1. Adaptation to climate change is inevitable

Adaptation strategies are inevitable as both gradual climate change and extreme climate and monsoon events are expected to be more profound in future. The basic premise of any action on climate change, therefore, should now be to promote adaptive capacity in the context of concurrent provisioning for sustainable livelihoods and sustainable development. In addition, there is a need for combining

disaster reduction, natural resource management and climate change adaptation in a new approach to the reduction of vulnerability and poverty and enhancement of resilience.

Therefore, learning the societal adaptation to climate change may provide ways to maintain resilience of the social and economic systems needed for sustainable development. It is important to know how do present-day village communities maintain resilience and adapt to abrupt climate variability. Also useful is to know how these adaptations can be enhanced in the face of the challenges posed by abrupt climate change. Adaptations are crafted by men and women both. They can be spontaneous or planned; mechanistic or value-based or a combination thereof. Adaptation can also be as 'hardware' (physical) such as water-harvesting structures, or software (i.e. institutions, norms etc.) such as village councils for collective irrigation management or groups of seasonal migration in fluctuating monsoons.

It is important to know how do present-day village communities maintain resilience and adapt to abrupt climate variability. Also useful is to know how these adaptations can be enhanced in the face of the challenges posed by abrupt climate change.

1.2. Why knowledge on Rajasthan is crucial?

Why some areas, such as Rajasthan, warrant priority in adaptation research? Rajasthan is an ideal geographical region for the study of societal adaptation to climate change. Antiquity of human occupation of the arid regions of Thar goes back to the late Pleistocene (last 1600000 years) or even earlier as indicated by archaeological studies. During the mid-Holocene, regions around the Indian Ocean witnessed rise of the three great civilizations of the world (i.e. Mesopotamian, Egyptian and Indus Valley). Indus-Saraswati Civilization (also called Indus-Harappa civilization or Indus Valley civilization) is the earliest known urban civilization in South Asia that flourished and fell in the region that includes parts of present-day Rajasthan.

Although controversy remains, there is now increasing evidence in favour of climate change as driver for societal disruption and collapse of Indus-Saraswati Civilization[12,13]. Some studies have implicated the climate change as the reason for the collapse of Indus Valley civilization[14,15]. This conclusion was not supported by other studies[16]; rather they suggested that chronology indicates that there is no relation between the proposed drought that caused the desiccation of the lakes and the collapse of the Indus valley civilization, as the lakes in the region dried out >1500 years earlier. Northwestern India

during the period of Indus-Saraswati Civilization experienced semiarid climatic conditions that are similar to those of present. However, recent studies[17] based on the planktonic oxygen isotope ratios off the Indus delta reveal climate changes with a multi-centennial pacing during the last 6 ka, with the most prominent change recorded at 4.2 ka BP. Contrasting isotopic trends across the northern Arabian Sea surface at that time indicate a reduction in Indus river discharge and suggest that later cycles also reflect variations in total annual rainfall over south Asia. The 4.2 ka event is coherent with the termination of urban Harappan civilization in the Indus valley. Thus, drought may have initiated southeastward habitat tracking within the Harappan cultural domain. The late Holocene drought cycles following the 4.2 ka BP event vary between 200 and 800 years and are coherent with the evolution of cosmogenic ^{14}C production rates. This suggests that solar variability is one fundamental cause behind Holocene rainfall changes over south Asia.

In more recent times, Rajasthan has experienced severe and frequent spells of droughts than any other region in India. Climate change presents a serious risk to poverty eradication and sustainable livelihoods. The adverse impact of climate change is more severely felt by poor people who are more vulnerable than rich. Appropriate policy responses can strengthen adaptation and help build the resilience of communities and households to climate change. Steps to promote the mainstreaming of adaptation into sustainable development may potentially deliver better results when combined with adaptive management of natural resources. Learning from the adaptations employed by the village communities of areas such as Rajasthan can provide insights to design useful policies and public actions.

More recently, Rajasthan has done comparatively well in the implementation of Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA). While the intention of the MNREGA is to provide a basic employment guarantee in rural areas, yet natural resource-based activities are also directly contributing to climate change mitigation and adaptation as well as enhancing the resilience and reducing the vulnerability of rural poor: (i) water conservation and water harvesting, (ii) drought proofing, including afforestation and tree plantation, (iii) irrigation canals, including micro and minor irrigation works, (iv) provision of irrigation facility, plantation, horticulture, and land development, (v) renovation of traditional water bodies, including desilting of tanks, (vi) land development, (vii) flood-control and protection works, including drainage in waterlogged areas. It would be useful to learn from more successful examples of such works and apply learning across all districts so that

MNREGA works provide multifunctional benefits such as reduction in poverty and vulnerability, improvement in resilience, climate change mitigation and adaptation.

1.3. Some Examples of Science-Based Policy Options

Policy-makers and practitioners would, however, need to be careful and aware that climate policy for adaptation and mitigation can not be static. Rather, society will need adaptive policy options to account for uncertainty associated with climate change. A valuable and comprehensive study on adaptive policy design can be very helpful in this endeavour[18]. We suggest that every policy-maker should draw on this study to design adaptive climate policy options. A useful guidance for designing adaptive policies anticipate and plan for a diversity of conditions that are in existence today and that are projected to arise in future (see ref[18] and chapters therein):

(i) *Using integrated and forward-looking analysis*: By identifying key factors that affect policy performance and how these factors might change in the future, we can make policies robust to a range of anticipated conditions, and accordingly initiate important policy adjustments when required.

(ii) *Monitoring key performance indicators to trigger built-in policy adjustments*: Inherent variability in social, economic and ecological conditions under which a policy must operate can be anticipated through scenario analysis, and local monitoring can help generate important policy adjustments to keep the policy functioning well.

(iii) *Undertaking formal policy review and continuous learning*: Even when the policy is performing well, regular review, and the use of well-designed pilot studies throughout the operation of the policy to test assumptions related to performance, can help address emerging issues and trigger important policy adjustments.

(iv) *Using multi-stakeholder deliberation*: It can help examine an issue from different points of view prior to taking a decision, and provides a comprehensive understanding of causal relationships.

Yet, not all situations can be anticipated. Therefore, uncertainty will always be part of policymaking. Adaptive policies are able to navigate toward successful outcomes in settings that cannot be anticipated in advance. This can be done by working in concert with certain characteristics of complex adaptive systems and thereby facilitating autonomous actions among stakeholders on the ground. To some

extent, last two adaptive policy tools noted above can be used toward this purpose, but more useful autonomous tools are as follows:

> (v) *Enabling self-organization and social networking*: Policies should not undermine existing social capital. Some of the processes that strengthen the ability of stakeholders to respond to unanticipated events include social networking, sharing of good practices, and removing barriers to self-organization.
>
> (vi) *Decentralizing decisionmaking to the lowest and most effective jurisdictional level*: Decentralization of the authority and responsibility for evidence-based decision-making to the lowest functional unit of governance facilitates policy to perform successfully.
>
> (vii) *Promoting variation in policy responses*: Given the complex interplay of social-ecological systems, policy contexts are increasingly becoming complex and diverse. Thus, implementing a variety of science-based policy options to address the same issue increases the likelihood of achieving desired outcomes.

These seven tools can be useful as pragmatic guide for policymakers working in highly complex, dynamic, and uncertain context such as presented by climate change challenges, and the consequent need for robust adaptation and mitigation.

One of the overarching insights emerging from the literature assembled here is that several activities covered under Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) address both poverty and climate change. The linkage is direct and visible because the land-based activities being done under MNREGA enhance resilience and reduce vulnerability, and thus contribute both to climate change adaptation and mitigation. For example, MNREGA works can significantly contribute to climate change mitigation through forest restoration by sequestering large amount of carbon in carbon-limited soils of Rajasthan. Likewise, water conservation, rainwater harvesting, land development and afforestation (including sequential restoration of sand dunes) can enhance the resilience of rural social-ecological systems. Ground-water recharge, enhanced soil fertility and increased biomass can address both biophysical and livelihoods adaptation. Many of the examples we provide in this section can be achieved through a careful mainstreaming with MNREGA.

It would be useful to give clear priority to those activities in Rajasthan that meet a combined set of seven climate-proofing criteria, which can be verified through measurable indicators for ecological,

economic and social sustainability[19]: (i) Reduction and/or sequestration of greenhouse gases, (ii) biodiversity conservation and ecosystem functioning, (iii) enhancing the yield of livelihoods goods and services to local people, (iv) reduction in poverty and vulnerability, and improving the resilience and adaptive capacity, (v) local empowerment and capacity development, (vi) synergy with objectives of international instrument and conventions, and (vii) coherence with local strategies for sustainable development.

The literature assembled here in this document is likely to be useful to generate policy options to address the challenges of climate change. In this section, we provide only a selection of examples—and not a comprehensive list of policy options—on using science to generate policy responses for Rajasthan. These examples are drawn from diverse domains such as water, energy, dryland and desert, protected areas, and urban systems. This selection of examples, hopefully, shall facilitate policymakers and practitioners working in diverse governance domains to use the literature included in this document for designing appropriate policy options for climate change mitigation and adaptation in Rajasthan.

1.3.1. Water Management

Rajasthan is the largest state in India covering an area of 34.22 million hectares, i.e., 10.5 percent of the country's geographical area, but sharing only 1.15 percent of its water resources. The estimated annual, per capita water availability in the state during 2001 was 840 m^3 and it is expected to remain 439 m^3 by the year 2050, against the national average of 1,140 m^3 by 2050 (see ref.[20]). Thus, as described earlier, a robust policy intervention is required for sustainable water management.

Rajasthan has two-third of its area as desert and it receives scanty rainfall. Out of 237 blocks in Rajasthan, only 49 are safe in terms of ground water while 101 are critical and semi critical and 86 are over exploited. State dependence on ground water is 91% for drinking water. About 21,190 villages/habitations suffer from the problem of excessive salinity, 23,297 villages/habitations suffer from excess fluoride problem and 20,659 villages/habitations suffer from excess nitrate problem[21]. Based on the WHO guidelines for drinking-water quality about 56% of the water sources are un-potable.

While the overall stage of groundwater development in India is 58%, Rajasthan has already reached 125 to 135%. Groundwater being the primary source of fresh water in Rajasthan, consumption is faster than it is naturally replenished[22]. This is causing serious decline in water tables. The robust long-term studies suggest that groundwater

is being depleted at a mean rate of 4.0 cm per year equivalent height of water, or 17.7 cubic kilometers per year in the region[23].

As noted earlier, on top of the above challenges, the State also falls within the areas of greatest climate sensitivity. In addition, the State has the maximum vulnerability and lowest adaptive capacity to climate change challenges. Rajasthan has the maximum probability of occurrence of drought in India. Condition may deteriorate in terms of severity of droughts in Rajasthan. Even though 20% rise in all-India summer monsoon rainfall is projected, in Rajasthan overall rainfall is projected to decrease, and evapotranspiration to increase, due to global warming. Even a marginal increase in evapotranspiration due to global warming will have a larger impact on resource-poor, fragile arid zone ecosystem of Rajasthan.

Water availability is fundamental to food security. Thus, adaptations in water sector shall also be vital for the future in order to prevent the rural exodus and guarantee food security for the population[24].

Thus, as a policy response, Rajasthan is required to be treated as a special area from climate change perspective and comprehensive water management plans for agriculture, domestic and industrial sectors should be supported by a special economic package and investments that help in: (i) large-scale construction and renovation of rainwater harvesting systems in rural landscape and urban public buildings; (ii) augmenting water infrastructure in urban and rural systems, including water supply, water desalination, and water treatment and recycling for industrial and domestic uses; (iii) large-scale infrastructure development for enhancing the groundwater replenishment; (iv) enhancing the preparedness through various inputs for drought mitigation, drought monitoring and development of early warning systems; (v) long-term insurance system to minimize the crop failure losses.

1.3.2. Management of Dryland Forests and Agroforestry

A recent comprehensive study[25] suggests that the forest cover in Rajasthan changed successively to 1.25, 1.33, 1.58 million ha respectively through the years 1982, 1992, 2002. In addition, the availability of biomass (tonnes ha^{-1}) has been increasing: from 13.46 to 13.61, and finally to 28.32 tonnes per ha for the year 1982, 1992 and 2002 respectively. Soil organic carbon in Rajasthan, however, is the lowest among Indian States, i.e., 70.08 tonnes per ha, compared to, for example, more than 138 tonnes per ha in Sikkim. This means that soils in Rajasthan are essentially carbon-limited. Average above ground biomass growth in Rajasthan is 1.55 $td.m.ha^{-1}yr^{1}$ (tonnes of dry matter per ha per year). The ratio of below ground biomass to

above ground biomass was highest in Rajasthan (i.e., 0.32) compared to, for example, 0.24 in Karnataka. This could be due to larger root systems in vegetation of arid lands.

Forests as carbon sinks, are required to play a multifunctional role that includes, but is not limited to, biodiversity conservation and maintenance of ecosystem functions; yield of goods and services to the society; enhancing the carbon storage in trees, woody vegetation and soils; and providing social and economic well-being of people. Thus, as a policy response, massive efforts for tree planting and restoration of forests in Rajasthan is required in order to encourage carbon sequestration and climate change mitigation. As discussed earlier, forest restoration is also consistent with the objectives of MNREGA. Management of multifunctional forests over landscape continuum, employing tools of conservation biology and restoration ecology, shall be the vital option for climate change mitigation in future[26].

In addition to forest resources as noted above, the land-use options outside forests that increase resilience and reduce vulnerability of contemporary societies are fundamental to livelihoods improvement and adaptation to climate change[27]. Agroforestry as a traditional land-use adaptation in Rajasthan supports livelihoods improvement through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change. The contributions of agroforestry systems are diverse: (i) biodiversity conservation; (ii) yield of goods and services to society; (iii) augmentation of the carbon storage in agroecosystems; (iv) enhancing the fertility of the soils; and (v) providing social and economic well-being to people. Thus, to promote well-being of the society, management of multifunctional traditional agroforestry systems of Rajasthan need to be strengthened by innovations in domestication of useful species and crafting market regimes for the products derived from agroforestry systems[28].

Another policy response shall be the recognition that enormous opportunities exist for synergizing MNREGA with ongoing agroforestry projects in India, and accordingly NREGA has high potential for contributing to mitigation and adaptation to climate change. An interesting analysis suggests that if each ongoing MNREGS work covers only 0.25 hectares, and if agroforestry interventions are applied only in ½ of that area (1/8th ha.), the existing NREGS 25.52 lakhs works, will be capable of sequestering 1.6 million tonnes of carbon[29].

1.3.3. Sequential Restoration of Dunes in Thar Desert

It is predicted in studies that due to climate change there may be significant increase in the desert area over India in next 100 years[30] with potentially disproportionate impact of global warming on coupled human and natural systems. Indeed, reactivation is likely to intensify further as global warming may force remobilization of desert dune systems in future[31]. Reactivated sand drift mediated by climate change and anthropogenic impacts may threaten the sustainability of agriculture, infrastructure and land resources in Rajasthan. These challenges call for re-examination and re-formulation of strategies for management of arid forests and dune vegetation.

Thar Desert in India is characterized by low and erratic rainfall, high air and soil temperature, intense solar radiation and high wind velocity. Context-specific interactions of these factors not only give rise to frequent drought and famines, they also make local livelihoods highly vulnerable.

Desert Development Programme (DDP) and Combating Desertification Programme (CDP) have been implemented over decades to address desertification control, protection to infrastructure, and improvement in green cover and local economy. These programmes have achieved the desired result of sand dune fixation, yet the resultant vegetation consists of only planted *Acacia tortilis* trees. In addition, the areas covered by these plantations have not been able to cover the vast expanse of sands fully. Paucity of multiple-layers of vegetation is now resulting in dune reactivation due to biotic and natural causes. Reactivation of sand drift exposes roots that cause tree uprooting at many places, and threatens the agricultural production due to moving sands. We, thus, need concurrent strategies for climate change adaptation, drought risk mitigation, carbon sequestration and livelihoods improvement.

By way of example, indigenous species *Calligonum polygonoides* provides 7.15 t ha^{-1} biomass at the age of 50 months, *Prosopis julliflora* provides 7.00 t ha^{-1} biomass after 50 months, and *Acacia tortilis* provides 5.24 t ha^{-1} biomass after 50 months[32]. Indeed, *Calligonum polygonoides* and *Cenchrus ciliaris* combination provides best yields of fodder and fuelwood, whereas combination with *Cassia angustifolia* was the best to control sand drift. A minimum of 4200 - 4600 kg C/km^2/year of soil organic carbon is likely being sequestered in soils under the plantations in arid region[33].

Thus, as a policy response, long-term financial support to implement a strategy for enhancing the biodiversity, productivity and livelihoods

through sequential restoration of vegetation in stabilized and reactivated dunes is required[34]. Historically, sand dune stabilization was an emergency and the rapid tree-cover developed through DDP and CDP has served the desired purpose (i.e., sand dune fixation, soil enrichment etc.), but could stabilize only limited areas. Owing to the green cover created through these interventions, soil properties and moisture regimes have improved. We now need to enhance biodiversity through enrichment of stabilized or reactivating dunes with indigenous species that were not possible to grow—or failed to grow—initially in moving dunes. Such sequential restoration is expected to enhance productivity, and initiate succession towards indigenous species that will further yield livelihoods goods and services to local people. Support for desert afforestation, thus needs to be strengthened.

1.3.4. Solar and Biomass-based Energy

As an alternative to fossil-fuel based energy, the Jawaharlal Nehru National Solar Mission (JNNSM) of the Government of India is aiming to promote the development and use of solar energy for power generation. Specifically, the aim is to create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022. The areas with annual direct solar radiation more than 1800 kWh/m^2 are best suited for installation of concentrating solar power (CSP) systems. The arid parts of Rajasthan receive average maximum solar radiation of about 7.5 kW h/m^2 in summers and minimum of about 4.6 kW h/m^2 in winters[35]. The results of a recent study[36] indicate that the use of CSP technologies make financial sense for Rajasthan where the financial performance indicators for the CSP systems are attractive for most of the locations such as Jaisalmer, Bikaner, Barmer, Kota, Jodhpur, Jobner, Udaipur, and Jaipur. In addition, benefits of carbon credits under clean development mechanism of the Kyoto Protocol further improve the financial feasibility of CSP systems.

Solar intensity in the western Rajasthan varies from 5.85 to 6.44 kWh/m^2/day. Sun is available for 345-355 days in a year because rains occur only for 10.4-20.5 days in a year. Therefore, there is high scope to harness solar energy for useful and profitable purposes[37].

In addition to solar power, about 1275 MW electrical power is possible to generate through biomass gasifier based power generation plant through surplus biomass available in Rajasthan. About 1656 tonnes of CO_2 can be saved annually by installation of 1 MW biomass gasifier based power plant[38].

This calls for aggressive efforts to promote the development and utilization of solar energy for concentrating solar power generation, and biomass-based power generation in Rajasthan.

1.3.5. Management of Protected Areas and Biodiversity

As discussed earlier, there is now ample evidence of the ecological impacts of recent climate change. Studies have reported coherent pattern of ecological change across systems. The responses of both flora and fauna span an array of ecosystems and organizational hierarchies, from the species to the community levels. Although we are only at an early stage in the projected trends of global warming, ecological responses to recent climate change are already clearly visible.

A coupling of land-use and climate change has led to substantial range contractions and species extinctions. Even more dramatic changes to global land cover are projected for this century. For example, Millennium Ecosystem Assessment scenarios to evaluate the exposure of all 8,750 land bird species to projected land-cover changes due to climate and land-use change suggests that at least 400 species are projected to suffer >50% range reductions by the year 2050 (over 900 by the year 2100)[39].

There is evidence in some regions of the world to show that climate change has resulted in population declines in long-distance migratory birds. Rajasthan, on account of several ancient lakes, has been a wintering-ground for many species of birds. Rajasthan's tourism economy is greatly dependent on the protected area tourism. Thus, we will have to strengthen the protected area management in such a way that reduces the impact of global warming.

In addition to climate change, habitat fragmentation has long history in Rajasthan. Patch area and isolation are important factors affecting the occupancy of many species. Therefore, providing an intervening corridor is an important conservation strategy for continued species survival. Improving corridor quality may lead to higher conservation returns[40] than manipulating the size and configuration present wildlife sanctuaries in Rajasthan.

New policy alternatives must be shaped by technical knowledge. Therefore, as a policy response, Rajasthan would need to strengthen the management of protected areas, both in terms of enhancing management effectiveness as well as expanded reserve network through provisioning of large-scale strategic corridors to minimize local biodiversity extinctions.

1.3.6. Management of Urban Forests

On the face of climate change, adaptation and mitigation actions for cities in India are critically required where the urban population is likely to grow by around 500 million over the next 50 years. Addressing multiple risks due to climate change—temperature and precipitation variability, drought, flooding and extreme rainfall, cyclone and storm surge, sea-level rise, and associated environmental health risk—is a serious public policy and adaptation management challenge[41]. Urban forests are one of the key ecological urban infrastructures.

A recent review of research-based knowledge[42] on the present status of urban forestry across the world provides lessons that can be applied for the governance of urban green spaces during the development of Jaipur as a world-class city in Rajasthan. In an era of global climate change and rapid urbanization, innovations on governance of urban systems are critically required as 50% people are now living in less than 3% of the earth's urbanized terrestrial surface. Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Both policy and science now emphasize the critical necessity of green areas within urban social-ecological systems. From the global perspective, although there are wide variations both in coverage as well as per capita availability of green spaces, cities renowned for their urban green spaces often have 20 to 30% coverage of the total geographical area, and 15 to 25 m^2 urban green spaces per capita. In Jaipur city, as per the existing land use analysis the area under park and open space is around 5.43 km^2 for a population of 3.30 million. Accordingly, per capita open space works out to be 1.60 m^2 per person. World Health Organization suggests ensuring at least a minimum availability of 9.0 m^2 green open space per city dweller.

Thus, as a policy response, strategies and lessons for connecting science to decision-making aimed at creating multifunctional landscapes to enhance urban resilience and human well-being in Jaipur are required. One of the most useful strategies for enhancing the urban green spaces in Jaipur would be to protect and develop adjoining forest lands—in accordance with Forest (Conservation) Act, 1980, and after carrying out appropriate environmental impact assessment—by investing in sequential restoration and enrichment of local biodiversity.

On the technical and governance issues following suggestions may be useful for creating multifunctional landscapes to enhance urban resilience and human well-being:

(i) strengthening the network of urban green spaces through linkages between various components; (ii) sequential restoration of existing urban forests and developing them into a multifunctional ecosystem; (iii) developing connectivity, as far as possible, among backyard habitats, urban domestic gardens, and public parks; (iv) integrating urban forest planning into regular master plans and urban development projects; (vi) maintenance of species diversity and spatial heterogeneity by planting three-tier vegetation (herbs, shrubs and trees): no more than 30% from one family, no more than 20% from one genus, and no more than 10% from one species (vii) designing and implementing the programme for local monitoring and local enforcement of locally-made rules for the management of urban forests, (viii) financial innovations such as entry fee for generating the resource to manage urban green spaces sustainably, (ix) treatment and recycling of wastewater—by deploying cutting-edge science & technology—for development and management of urban green spaces.

1.3.7. Mine-Spoil Restoration

Rajasthan presents evidence for the existence of one of the most advanced works of ancient mining globally. Mining continues to be an important economic activity in Rajasthan. However, economic benefits of mineral extraction also accompany environmental, economic and social costs. Mine waste dumps and mined out areas viewed simply as the legacies of past may appear overwhelming environmental hazards presenting ugly picture of cultural landscape. However, mine wastes can be transformed into an opportunity for climate change adaptation, carbon sequestration and productivity enhancement for sustainable livelihoods through ecological restoration.

As a policy response, we need to draw on sustainability science to address the imperiled nature-society interactions to construct a self-sustaining multifunctional ecosystem capable of supporting biodiversity, performing ecosystem functioning and providing ecosystem services to strengthen livelihoods. It should also be in coherence with the prevailing policies and actions on water, mineral, wildlife and forest. Policy response should also essentially provide benefits in terms of climate change mitigation and adaptation.

The main physical problems with mine spoils in Rajasthan are shallow substrate of soil (or often lack of it), large cavities in the very coarse-grained substrate, very high stone content, extremely coarse texture, compaction, and the limited availability of moisture. In order to overcome these challenges, dredging and sediment removal from traditional tanks and ponds can potentially be used to prepare the

substratum over the mine wastes for direct seeding and planting[43]. Sediment excavation from ponds and lakes will also simultaneously create enhanced decentralized water storage capacity for wildlife and people. Thus, holistic strategy combines the concurrent revival of traditional water harvesting systems, ground water recharge, enhanced biomass production and an adaptation to random recurrence of droughts in Rajasthan[44]. In addition, there are clear opportunities for synergizing MNREGA with mine-spoil restoration and renovation of local rainwater harvesting systems.

1.3.8. The Network of Mega-Shelterbelts

The general perception of human population inhabiting over the region between Bikaner to Ramgarh in Rajasthan is that the climate extremes have ameliorated due to plantation in the region. Often cited reason for this has been that in Indira Gandhi Canal command the density and area of vegetation cover have increased due to afforestation, and the cultivated area has expanded due to irrigation[45]. In addition, starting in 1960s, Rajasthan Forest Department has also covered about 38,000 row km area under shelterbelt, road side, railway line and canal side plantations[46]. The impact of shelterbelt on agricultural returns has been shown to be substantial in the region[47].

As the predominant wind direction in Rajasthan is South West to North East, the tendency for desertification has been more in that direction. Indeed, there is clear evidence that the Thar Desert is expanding in an eastward as well as northeast direction[48]. Thus, from the climate-proofing perspective, creating plantation strips and shelterbelts perpendicular to the predominant wind direction in areas spread from Ramgarh to the foothills of Mount Abu is likely to help in climate change mitigation and livelihoods improvement.

Furthermore, shelterbelt network proposed here can further be reinforced by creation of avenue plantations along the major roads. Rajasthan has a network of about 180,000 km roads. Many roads, particularly those running north and south, are placed more or less perpendicular to often prevailing direction of winds. Thus, avenue plantations along roadside can strengthen the overall shelterbelt network.

The proposed network of mega-shelterbelts is expected to serve several purposes:

(i) Cost reduction in road maintenance due to reduced extremes of alternate heating and cooling of the road surface;

(ii) Active pollutant removal;

(iii) Interception of particulate matter and dust-storms;

(iv) Networked-arrest of long-distance windblown sand as majority of wind flow is often likely to strike these mega green-avenues in near perpendicular direction;

(v) Enhanced resilience of road network;

(vi) Moderation of local micro-climate, and

(vii) Climate change mitigation benefits (such as carbon sequestration), and adaptation benefits to neighbouring farmlands.

This proposal of mega-shelterbelts begs the question if this idea will work in practice? The Great Green Wall of China could be offered here as a case for some insights. Great Green Wall is a series of human-planted forest strips in the People's Republic of China, designed to hold back the Gobi Desert. It is said to be one of the most aggressive weather modification programs in the twentieth century. The planting project is expected to take over 70 years, and likely to be completed by the year 2074. When complete, it is expected to be 4,500 km long[49]. In general, dust storms have reduced in most regions of China from the 1950 to 2000 (see ref.[50]), consistent with an earlier negative trend in dust-storm frequency and duration during 1960-1994 period[51].

1.3.9. Science to generate policy options

The science-based insights shall remain crucial to generate and implement policy options to address the challenges of climate change. As noted earlier, we have provided only a selection of examples, in above sections, on using science to generate policy responses for Rajasthan. The next chapter provides abstracts of the research articles and publications that policymakers can use to design evidence-based policy responses in various domains of governance.

2.

Knowledge for Action

Annotated Bibliography

1. Achyuthan, H., A. Kar and C. Eastoe (2007). **"Late Quaternary-Holocene lake-level changes in the eastern margin of the Thar Desert, India**." Journal of Paleolimnology **38**(4): 493-507.

A study on two closed salt lake basins, Tal Chapar and Parihara in the eastern margin of the **Thar Desert**, **Rajasthan**, was carried out to unravel late Quaternary geomorphic evolution of these saline lakes. Both lakes are elliptical in shape bordered by stabilised dunes, and are oriented in a NE-SW direction, i.e., in the direction of the prevailing summer monsoon wind. Both lakes have been formed in the wind-shadow zones of isolated hills of Precambrian quartzite. This study indicates that the late Quaternary sediments in the lakes began with the cyclic deposition of laminated fine silt layers (0.5 m thick), rich in organic matter, alternating with ripple cross-bedded sand layers (each ~1.5–2 m thick). Sand layers that are moderately sorted are separated by laminated silt-clay layers with gypsum/calcite and this unit occurs in the upper most 4 m sequence in deeper sections. The presence of gypsum crystals within the laminated sediments suggests a high concentration of Ca in the inflowing water. At Parihara Lake the organic carbon-rich sediments at 95 cm depth was dated to 7,375 + 155/−150 year BP. At Tal Chapar radiocarbon dates of 7,190 + 155/−150 and 9,903 + 360/−350 was obtained from the sediments rich in organic carbon occurring at a depth of 1.35 m and 1.80 m, respectively. The study reveals strong hydrologic oscillations during the past ~14,000 year BP (13,090 + 310/−300 year BP). Quaternary geomorphic processes, especially the strong aeolian processes during dry climatic phases, played a major role in the formation of the lake basins, as well as the fringing linear dunes. Geochemical and mineralogical analyses of the lacustrine sediments, supported by radiocarbon dates indicate the existence of an ephemeral lake earlier than ~13,000 year BP as sediments began to be deposited in a lacustrine environment implying sustained runoff in the catchments. A freshwater lake formed between 9,000 year and 7,000 year BP. The lake dried periodically and this strong fluctuating regime continued until about ~7,000 year BP. Mid-Holocene was wet and this was possibly due to higher winter rains A saline lake existed between 6,000 year and 1,300 year BP and finally present day semi arid conditions set in since 1,200 year BP. Remnants of a habitation site (hearth and charred bones) on stabilised dune at Devani near Tal Chapar were dated to 240 ± 120 year, while that at Gopalpura was dated to 335 ± 90 year. These historical sites on stabilised dunes were, according to the local accounts, settlements of people who used the lake brine for manufacturing salt.

2. Ahluwalia, M. (1997). "**Representing communities: The case of a community-based watershed management project in Rajasthan, India.**" IDS Bulletin **28**(4): 23-34.

Focusing on a community-based watershed project in Rajasthan implemented by Seva Mandir, this article applies the tools of environmental entitlements analysis in a project evaluation mode to explore the effects of social difference on project experience and impact. Seva Mandir's investments in capabilities and social capital have successfully facilitated 'community' identity and action, across caste, class and gender differences, in the context of local political struggles. Yet natural resource management remains an arena of conflict: while certain stakeholders have benefited from soil and moisture conservation activities and the enclosure of commons, others - especially pastoralists and women - have faced high costs to their livelihoods.

3. Ajai, A. S. Arya, P. S. Dhinwa, S. K. Pathan and K. G. Raj (2009). "**Desertification/land degradation status mapping of India**." Current Science **97**(10): 1478-1483.

This paper describes the classification system, methodology and the results of desertification and land degradation status mapping carried out for the entire country on 1: 500,000 scale using multi-temporal Resourcesat AWiFS data. The study reveals that 105.48 mha area of the country is undergoing processes of land degradation (32.07% of the total geographic area of the country). Area undergoing desertification is 81.4 mha. Statewise distribution of area under land degradation is given in Table 2. **Rajasthan** has the largest area (21.77% of the TGA) under land degradation, followed by J&K (12.79% of TGA), Maharashtra (12.66% of TGA) and Gujarat (12.72% of TGA). Nearly one third of the country's land area (32.07%) is undergoing processes of land degradation. There are about eight major processes of land degradation active in the country. Water erosion is the most pronounced process, followed by vegetal degradation and eolian processes. Area-wise **Rajasthan**, J&K, Gujarat and Maharashtra have high proportions of land undergoing degradation. 81.45 mha land area of the country is undergoing the process of desertification.

4. Akermann, K., L. Herberg and A. Kalisch (2009). "**How do small farmers respond to climate change in Rajasthan?**" Rural 21 **4**: 30-32.

Water is scarce in India's semiarid zones of **Rajasthan**. Climate change is putting additional pressure on the rare resources. Irregular or no rainfall forces many small farmers to abandon their fields, at least temporarily, and seek work in the towns. Participative

water management projects as practiced in Bhipur village, growing crops with low water requirements and more sustainable farming practices are adaptation strategies that allow farmers to continue their activities despite climate risks. Such adaptation approaches are vital for the future in order to prevent the rural exodus and guarantee food security for the population.

5. Akhtar, R. (2010). "**El Niño related health hazards in India**." Current Science **98**(2): 144-147.

There is the growing concern of the impact of climate change and variability including rainfall anomaly, rising temperature in mountain areas and occurrence of heat waves in relation to human mortality pattern in India. The paper investigates the historical perspective of rainfall and malaria relationship, and discusses current studies to show how climate change and variability resulted in large scale human loss in India. Based on data on rainfall pattern in the desert part of Rajasthan, the paper argued that the rainfall pattern is changing. The paper also argued that global warming has resulted in increased heat wave conditions in India and accordingly resulting in increased deaths due to heat wave conditions in different parts of India, particularly in the northwestern, south, and southeastern regions. Analysis of data for Bikaner and Jodhpur of **Thar Desert** showed that summer monsoon rainfall decreased steadily by more than 45% since 1957. The heat wave occurrence and malaria outbreak in western **Rajasthan** do suggest the role of El Niño in health hazards. The current El Niño has also been considered very strong resulting in widespread drought conditions in India. The impact of heat waves as well as malaria epidemics could be minimized by prediction and improved prevention through timely heat wave warnings; vector control and provision of sufficient drugs in dispensaries/health centres. Malaria early warning systems are advocated as a means of improving the opportunity for preparedness and timely response.

6. Anderson, D. M., J. T. Overpeck and A. K. Gupta (2002). "**Increase in the Asian southwest monsoon during the past four Centuries.**" Science **297**(5581): 596-599.

Climate reconstructions reveal unprecedented warming in the past century; however, little is known about trends in aspects such as the monsoon. Authors reconstructed the monsoon winds for the past 1000 years using fossil Globigerina bulloides abundance in box cores from the Arabian Sea and found that monsoon wind strength increased during the past four centuries as the Northern Hemisphere warmed. It is inferred that the observed link between Eurasian snow cover and the southwest monsoon persists on a centennial scale.

Alternatively, the forcing implicated in the warming trend (volcanic aerosols, solar output, and greenhouse gases) may directly affect the monsoon. Either interpretation is consistent with the hypothesis that the southwest monsoon strength will increase during the coming century as greenhouse gas concentrations continue to rise and northern latitudes continue to warm.

7. Asif, M. and T. Muneer (2007). "**Energy supply, its demand and security issues for developed and emerging economies**." Renewable and Sustainable Energy Reviews 11(7): 1388-1413.

Energy is inevitable for human life and a secure and accessible supply of energy is crucial for the sustainability of modern societies. This article provides an overview of the current and projected energy scene. China, India, UK and USA are all net importers of energy and are heavily dependent on imports of fuel to sustain their energy demands. Their respective local oil reserves will only last 9, 6, 7 and 4 years, respectively. China, the emerging economy in the world, is however making exemplary development in renewable energy—in 2004 renewable energy in China grew by 25% against 7–9% growth in electricity demand. While in the same year, wind energy in China saw a growth of 35%. China is also leading the global solar thermal market as it has already installed solar collectors over 65 million square meters, accounting for more than 40% of the world's total collector area. It is argued that to meet 50% of the total energy demands the proposed area for collection of solar and wind energy by means of ultra-large scale farms will occupy a mere fraction of the available land and near-offshore area for the respective countries, e.g. a solar PV electricity farm of 61 km^2 for China represents 0.005% of the Gobi desert. Likewise, the 26 and 36 km^2 PV farm area, respectively, required for India and the US represents 0.01% and 0.014% land area of **Rajasthan** and Baja deserts.

8. Attri, S. D. and L. S. Rathore (2003). "**Simulation of impact of projected climate change on wheat in India**." International Journal of Climatology **23**(6): 693-705.

Climate change scenarios projected by the middle of the current century, based on the latest studies, were created and the impacts of concurrent changes of temperature and CO_2 on the growth, development and yields of wheat in northwest India were quantified using a state-of-the-art dynamic simulation model. Yield enhancements of the order of 29-37% and 16-28% under rainfed and irrigated conditions respectively in different genotypes were observed under a modified climate (T_{max} + 1.0°C, T_{min} + 1.5°C, 2 × CO_2). Any further increase beyond 3 °C cancelled the beneficial impact of enhanced CO_2. Adaptation measures to mitigate the potential impact

of climate change included possible changes in sowing dates and genotype selection. Enhancement of sowing by 10 days in late-sown cultivars and delaying of sowing by 10 days in normally sown cultivars resulted in higher yields under a modified climate, whereas a reduction in yield was observed in the reverse strategies.

9. Bandyopadhyay, A., A. Bhadra, N. S. Raghuwanshi and R. Singh (2009). **"Temporal trends in estimates of reference evapotranspiration over India."** Journal of Hydrologic Engineering **14**(5): 508-515.

Evapotranspiration (ET) is likely to be greatly affected by global warming because of the dependence of ET on surface temperature. The increasing atmospheric concentration of carbon dioxide (CO_2) and other greenhouse gases is expected to increase precipitation and evaporation proportionally. However, a few studies have shown a decreasing trend for evaporation over the last 50 years globally. In India, earlier works showed that there was a significant increasing temporal trend in surface temperature and a decreasing trend in reference ET (ETo). To study the temporal trend of ETo along with its regionwise spatial variation, 32 years (1971–2002) monthly meteorological data were collected for 133 selected stations evenly distributed over different agro-ecological regions (AERs) of India. ETo was estimated by the globally accepted Food and Agriculture Organization (FAO) Penman Monteith (PM) method (FAO-56 PM). These ETo values were then analyzed by a nonparametric Mann–Kendall (MK) test (with modified effective sample size approach for serially correlated data) and Sen slope to determine the existence and magnitude of any statistically significant trend over the time period considered in this study. The same analysis was also performed on governing meteorological variables to identify the cause of existence of such trend in ETo. A significant decreasing trend was found in ETo all over India during the study period, which was mainly caused by a significant increase in the relative humidity and a consistent significant decrease in the wind speed throughout the country. However, a general increase in rainfall was not found in recent years.

10. Bhandari, M. M. (1974). **"Famine foods in the Rajasthan Desert."** Economic Botany **28**(1): 73-81.

Information is given on the plants used as emergency food by the people of the **Rajasthan** Desert during periods of famine. The utilization of little known foods in times of acute crisis is urged. Several indigenous crop species are described which could be grown and utilized to prevent a great deal of suffering. More research is

called for to introduce new species of crops likely to succeed in drought conditions.

11. Bharara, L. P. (1980). **"Social aspects of drought perception in arid zone of Rajasthan."** Annals of Arid Zone **19**(1/2): 154-167.

Desert rural folk in **Rajasthan**, India perceive drought as a multi-dimensional phenomenon varying from meteorological to bio-physical to socio-religious in nature. Among various notions concerning the causes of drought, 77% of the responses were meteorological, exhibiting climatic changes; 49% bio-physical, bringing devastation of natural vegetation; and 33% socio-religous, with supernatural beliefs. Associated with these notions, folk reported drought-induced problems: distress sale of land, livestock, personal assets; set-back to occupational caste's economy; and loss of crop-livestock production. Biophysical problems revealed indiscriminate cutting of vegetation for fuel, construction, field bunding; traditional practices of overgrazing and frequent lopping of trees by livestock raisers; shifting soils affecting cultivated fields, pastures, barren lands and village ponds/wells. Social disorder revealed migration, occupational diversification, social loss and shifting settlements. Farmer's classification of past droughts revealed that droughts before 1970 were more severe. Changes in climatic and vegetational characteristics, animal behaviour and social behavioural activities are widely believed to be means of drought prediction.

12. Bharara, L. P. (1980). "**Socio-economic consequences of drought in an arid tract: case study**." In, H. S. Mann, ed. Arid Zone Research and Development. Scientific Publishers, Jodhpur, India, pp. 439-445.

The study, conducted in Shergarh Tehsil, western **Rajasthan**, analyses the nature and extent of the drought-affected area, social changes including social and economic values, disturbances in the agrarian sector, and changes in livestock numbers. Analysis of rainfall data for 78 years (1899-1976) revealed that there were 43 mild drought years when 50 percent of the crops reached maturity, 19 drought years (25 percent crop maturity), and 8 disastrous years (zero crop maturity). Social changes during drought years included a breakdown in the caste system and increased cooperation among people forced to migrate to find a livelihood. Analysis of land use changes revealed a positive correlation between the intensity of drought and the extent of the area damaged. Mean annual yield of kharif crops decreased from 90-100 percent in a drought year and 30-66 percent in a moderately deficit year. Livestock losses ranged from 17 percent for goats to 50 percent for cattle during drought years.

13. Bharara, L. P. and K. Seeland (1994). **"Indigenous knowledge and drought in the arid zone of Rajasthan: weather prediction as a means to cope with a hazardous climate**." Internationales Asienforum **25**(1/2): 53-71.

The paper identifies traditional social indicators of drought prediction in an arid region of **Rajasthan**, India and compares their accuracy with that of rainfall data as a contribution to the discussion of the relevance of indigenous knowledge to the development process in a predominantly rural society. The study was carried out in three different ecological areas: pastoral nomadic, mostly rainfed and rainfed with irrigation. The comparison showed minor differences in the way a year was perceived on the basis of folk memory and actual rainfall but the holistic approach, taking account of a number of indicators, gave a more accurate picture of the real situation than mere figures on precipitation.

14. Bhati, T. K., R. K. Goyal and H. S. Daulay (1997). **"Development of dryland agriculture on watershed basis in hot arid tropics of India: A case study."** Annals of Arid Zone **36**(2): 115-121.

A study on watershed management was initiated in 1986-87 at Jhanwar village (District, Jodhpur) and surveys were conducted to assess the problems, resources and potential of the area. The action plan was prepared and implemented. Farmers in the watershed area showed keen and sustained interest in adoption of improved dryland farming technologies, including sustainable land use systems. Productivity analysis of watershed area indicated considerable improvement in gross monetary returns under different cropping systems. Water harvesting, through creation of farm ponds and its recycling in agro-horticulture (Ziziphus mauritiana) system resulted in diversified production (fruit, fuel and fodder) and sustained 1.14 adult cattle unit ha^{-1} yr^{-1}. Development of pastures in community grazing lands increased forage production (2-3 t ha^{-1}) over traditional methods (0.3-0.4 t ha^{-1}). Adoption of various physical and biological land treatments in the eroded rocky catchment reduced the soil erosion and increased the ground water recharge. The program has resulted in an overall increase in the productivity by 25-30%.

15. Bhattacharya, S., C. Sharma, R. C. Dhiman and A. P. Mitra (2006). **"Climate change and malaria in India**." Current Science **90**(3): 369-375.

The focus in this paper is to understand the likely influence of climate change on vector production and malaria transmission in India. A set of transmission windows typical to India have been

developed, in terms of different temperature ranges for a particular range of relative humidity, by analysing the present climate trends and corresponding malaria incidences. Using these transmission window criteria, the most endemic malarious regions emerge as the central and eastern Indian regions of the country covering Madhya Pradesh, Jharkhand, Chhatisgarh, Orissa, West Bengal and Assam in the current climate conditions. Applying the same criteria under the future climate change conditions (results of HadRM2 using lS92a scenario) in 2050s, it is projected that malaria is likely to persist in Orissa, West Bengal and southern parts of Assam, bordering north of West Bengal. However, it may shift from the central Indian region to the south western coastal states of Maharashtra, Karnataka and Kerala. Also the northern states, including Himachal Pradesh and Arunachal Pradesh, Nagaland, Manipur and Mizoram in the northeast may become malaria prone. The duration of the transmission windows is likely to widen in northern and western states and shorten in the southern states. The extent of vulnerability due to malaria depends on the prevailing socio-economic conditions. The increase or decrease in vulnerability due to climate change in the 2050s will therefore depend on the developmental path followed by India. Therefore it is important to understand the current adaptation mechanisms and improve the coping capacities of the vulnerable section of the population by helping to enhance their accessibility to health services, improved surveillance and forecasting technologies. [Rainfall during October over Gujarat, Maharashtra, **Rajasthan**, Madhya Pradesh, Karnataka and Andhra Pradesh is positively correlated with malaria incidences in following year in these areas (with correlation coefficient, 0.52). This is because the rainfall in October in the previous year creates favourable conditions for a good vegetation growth and hence retention of optimum humidity conditions required for breeding of the mosquitoes in the subsequent year.]

16. Bhattacharyya, T., D. K. Pal, P. Chandran, S. K. Ray, C. Mandal and B. Telpande (2008). **"Soil carbon storage capacity as a tool to prioritize areas for carbon sequestration."** Current Science **95**(4): 482-494.

The present study aims at explaining the role of soils as one of the most important natural resources in enhancing carbon capture and storage (CCS). Soils capture and store both organic and inorganic forms of carbon and thus act both as source and sink for atmospheric CO_2. The datasets developed on CCS of soils permit us to generate thematic maps on soil carbon stocks, which may serve as ready reckoners for planners in prioritizing C sequestration programmes. [Criteria such as soil organic carbon stock per unit area

as well as point data for individual soils indicate that vast areas in the arid, semi-arid and drier parts of the sub-humid regions should get priority for organic carbon management. The total prioritized area has been worked out as 155.8 mha (arid: 49 mha, semi-arid: 116.4 mha and sub-humid: 34.5 mha.]

17. Bhuiyan, C., R. P. Singh and F. N. Kogan (2006). "**Monitoring drought dynamics in the Aravalli region (India) using different indices based on ground and remote sensing data**." International Journal of Applied Earth Observation and Geoinformation **8**(4): 289-302.

The hard-rock hilly Aravalli terrain of **Rajasthan** province of India suffers with frequent drought due to poor and delayed monsoon, abnormally high summer-temperature and insufficient water resources. In the present study, detailed analysis of meteorological and hydrological data of the Aravalli region has been carried out for the years 1984-2003. Standardised Precipitation Index (SPI) has been used to quantify the precipitation deficit. Standardised Water-Level Index (SWI) has been developed to assess ground-water recharge-deficit. Vegetative drought indices like Vegetation Condition Index (VCI) and Temperature Condition Index (TCI) and Vegetation Health Index (VHI) have been computed using NDVI values obtained from Global Vegetation Index (GVI) and thermal channel data of NOAA AVHRR satellite. Detailed analyses of spatial and temporal drought dynamics during monsoon and non-monsoon seasons have been carried out through drought index maps generated in Geographic Information Systems (GIS) environment. Analysis and interpretation of these maps reveal that negative SPI anomalies not always correspond to drought. In the Aravalli region, aquifer-stress shifts its position time to time, and in certain pockets it is more frequent. In comparison to hydrological stress, vegetative stress in the Aravalli region is found to be slower to begin but quicker to withdraw.

18. Bhuiyan, C., W. A. Flügel and R. P. Singh (2009). "**Erratic monsoon, growing water demand, and declining water table.**" Journal of Spatial Hydrology **9**(1): 1-19.

In India, water resources are governed by the southwest monsoon. The water demand is increasing day by day due to population growth, rapid urbanisation, and multiple cropping practices. Due to changing climatic conditions monsoon, the chief controller of rainfall is found to be very irregular. In the present study, an attempt has been made to assess relative influence of different controlling factors on ground-water recharge. Spatio-temporal variations of rainfall, potential evapotranspiration, ground-

water draft and consequent water-table fluctuations in the **Aravalli** terrain have been analysed using GIS. Visual comparison points out significant decrease in aquifer-recharge and variation in its spatial patterns in yearly and decadal scales owing to large variations in the seasonal rainfall distribution and over-exploitation of the limited water resources. Wells and zones could be demarcated where water table is depleting since a decade, irrespective of change in the rainfall scenario.

19. Billett, S. (2010). **"Dividing climate change: global warming in the Indian mass media."** Climatic Change **99**(1): 1-16.

The communication of climate change from scientists and policy-makers to the public via the mass media has been a subject of major interest because of its implications for creating national variation in public understanding of a global environmental issue. However, to date, no study has assessed the situation in India. India is the world's largest democracy. Physically, the country's population of 1.03 billion, 70% of which still lives in rural areas, surviving largely on subsistence farming or labouring, as well as its location on the Himalayan-fed South-Asian mega-deltas, make it highly vulnerable to the effects of climate change. As one of the major emerging economies, and so one of the major greenhouse gas emitters, India is a key actor in the climate change story. This study analyses the four major, national circulation English-language newspapers to quantify and qualify the frames through which climate change is represented in India. The results strongly contrast with previous studies from developed countries; by framing climate change along a 'risk-responsibility divide', the Indian national press set up a strongly nationalistic position on climate change that divides the issue along both developmental and postcolonial lines.

20. Bokil, M. (2000). **"Drought in Rajasthan: in search of a perspective**." Economic and Political Weekly **35**(48): 4171-4175.

This paper develops a systematic perspective on drought in **Rajasthan**, India, to guide both policy and practice. Drought conditions in the state (where 60% is arid, and the remaining is semi-arid) are discussed. Reference is made to Amartya Sen's *Poverty and Famine* which looks at the phenomena of famines from the entitlement approach. This approach concentrates on the ability of people to command food through the legal means available to society, including the use of production possibilities, trade opportunities, entitlements vis-a-vis the state, and other methods of acquiring food. Broad strategies of drought mitigation through the entitlement approach are outlined, including the provision of gainful employment for landless labourers. It is argued that drought in arid

and semi-arid regions is not a calamity, but a regular climatic feature. Instead of restoring to calamity relief, governments should consider drought mitigation as the principal strategy of agricultural and rural development.

21. Boykoff, M. (2010). **"Indian media representations of climate change in a threatened journalistic ecosystem."** Climatic Change **99**(1): 17-25.

Mass media translations of climate change predicaments and progress remain key influences that shape discourses and bound considerations for possible climate mitigation and adaptation actions. Assessments of Indian media representational practices against this backdrop of global trends may provide mixed feelings of both hope and despair. While there is a steady increase in the amount of Indian English-language national newspaper coverage of climate change, new research elsewhere finds largely hackneyed and arguably unproductive discourses along a risk-responsibility divide. While the 'light' may be on in this space, separations (inside and outside) and communication difficulties remain. Shifts in media discourses in the India—planet Earth's largest democracy—may be a harbinger of the shape and scale of the ongoing challenges of North–South relations, perceptions of risk, questions of responsibility, and issues of mitigation, adaptation, justice and equality. While multi-scale political economic forces may cause this media light to flicker and flutter, it continues to illuminate possibilities for our collective future.

22. Brenkert, A. and E. Malone (2005). **"Modeling vulnerability and resilience to climate change: A case study of India and Indian States**." Climatic Change **72**(1-2): 57-102.

The vulnerability of India and Indian states to climate change was assessed using the Vulnerability-Resilience Indicator Prototype (VRIP). The model was adapted from the global/country version to account for Indian dietary practices and data availability with regard to freshwater resources. Results (scaled to world values) show nine Indian states to be moderately resilient to climate change, principally because of low sulfur emissions and a relatively large percentage of unmanaged land. Six states are more vulnerable than India as a whole, attributable largely to sensitivity to sea storm surges.

23. Bryson, R. A., A. M. Swain. (1981). "**Holocene variations of monsoon rainfall in Rajasthan**." Quaternary Research **16**(2): 135-145.

Two reconstructed histories of the monsoon rainfall in **Rajasthan** show that the monsoon was weak or absent in latest glacial time. With the advent of Holocene climatic patterns, fresh

water lakes formed in dune fields and the pollen rain preserved in these reservoirs provides a basis for the reconstruction of the monsoon history. The reconstructions show maximum monsoon amounts in the early Holocene, with a roughly two-thirds decrease to the present. Reconstructions also show long intervals of near complete desiccation in the last four millennia.

24. Cash, D. W., W. C. Clark, F. Alcock, N. M. Dickson, N. Eckley, D. H. Guston, J. Jager and R. B. Mitchell (2003). "**Knowledge systems for sustainable development**." Proceedings of the National Academy of Sciences **100**(14): 8086-8091.

This study suggests that efforts to mobilize S&T for sustainability are more likely to be effective when they manage boundaries between knowledge and action in ways that simultaneously enhance the salience, credibility, and legitimacy of the information they produce. Effective systems apply a variety of institutional mechanisms that facilitate communication, translation and mediation across boundaries.

25. Chatterjee, K., A. Chatterjee, and S. Das. 2005. "**Community adaptation to drought in Rajasthan**." IDS Bulletin **36**(4): 33-52.

This case study focuses on traditional adaptation practises used by vulnerable communities in the drought-prone Tonk district, **Rajasthan**. Communities here already bear the brunt of drought and have learnt to cope. Successive droughts over wider geographic areas, combined with other stresses, now threaten to overwhelm coping capacity in ways that might become the norm with climate change. New adaptation strategies have been introduced in Tonk by local non-governmental organisations that build on existing knowledge and expertise about water, agriculture and livestock management. These include: growing new crops such as vegetables, fodder and higher value medicinal crops for commercial sale; use of environmentally sound fertilisers (vermiculture); improved storage for fodder and food grains; and improved water conservation and harvesting techniques through bunding of fields, construction of *anicuts* and digging and deepening ponds and wells. The growing number of people subject to successive droughts in **Rajasthan** (40 million in 2002-3) suggests, however, re-examination of state and federal policies, such as the National Agricultural Insurance Scheme, would be prudent to ensure these strategies are available to the most vulnerable, in order to prevent, rather than respond to, disaster.

26. Chatterjee, R. and R. R. Purohit (2009). "**Estimation of replenishable groundwater resources of India and their status of utilization**." Current Science **96**(12): 1581-1591.

The annual replenishable groundwater resources of India has been estimated as 433 billion cubic metre (bcm) and net annual groundwater availability as 399 bcm. The annual groundwater draft for 2004 was 231 bcm. Thus, the overall stage of groundwater development is 58%, but in **Rajasthan** the ground water development is 125%. Out of 5723 assessment units in the country, 4078 are 'safe' and 839 are 'overexploited'. The rest fall under 'semi-critical' and 'critical' category. Over-exploitation is more prevalent in northwestern, western and Peninsular India. Eastern India has good potential for future groundwater development.

27. Chattopadhyay, N. and M. Hulme (1997). "**Evaporation and potential evapotranspiration in India under conditions of recent and future climate change**." Agricultural and Forest Meteorology **87**(1): 55-73.

Evaporation time series data were analysed for different stations in India, and for the country as a whole, for different seasons on both a short-term (15 years) and long-term (32 years) basis for pan evaporation and on a short-term basis alone for potential evapotranspiration. The analysis showed that both pan evaporation and potential evapotranspiration have decreased during recent years in India. Future scenarios of potential evapotranspiration, and its component energy and aerodynamic terms, for India based on results from six global climate model climate change experiments are also calculated and intercompared. Future climatic warming appeared likely to lead in general to increased potential evapotranspiration over India, although this increase is likely to be unequal between regions and seasons. Such changes could have marked implications for the economy and society, particularly if the increases in evaporation are not compensated by adequate increases in rainfall.

28. Chaudhury, S. K., J. M. Gore and K. C. S. Ray (2000). "**Impact of heat waves over India**." Current Science **79**(2): 153-157.

A severe heat wave condition exists when the day temperature exceeds the normal maximum temperature over the place, by 6°C.During 1978–1999, the number of heat waves over Bihar, **Rajasthan** and Uttar Pradesh (UP) is more during the month of June compared to other months. The loss of human lives is found to be maximum in **Rajasthan** followed by Bihar, UP and Orissa.

29. Chhabra, A. and V. K. Dadhwal (2004). "**Assessment of major pools and fluxes of carbon in Indian forests**." Climatic Change **64**(3): 341-360.

Based on growing stock-volume approach at the state and district levels, the Indian forest phytomass was estimated in the range

of 3.8–4.3 PgC. The totalsoil organic pool in the top 1m depth was estimated as 6.8 PgC, using estimated soil organic carbon densities and Remote Sensing (RS) based area by forest types. Based on 122 published Indian studies and RS-based forest area, the total litterfall carbon flux was estimated as 208.8 $MgCha^{-1}$ yr^{-1}. The cumulative net carbon flux (1880–1996) from Indian forests (1880–1996) due to landuse changes (deforestation, afforestation and phytomass degradation) was estimated as 5.4 PgC, using a simple book-keeping approach. The mean annual net C flux due to landuse changes during 1985–1996 was estimated as 9.0 TgC yr^{-1}. For the recent period, the Indian forests are nationally a small source with some regionsacting as small sinks of carbon as well. In **Rajasthan**, forest area, above ground, below ground and total phytomass carbon in forests for the year 1993 were 1.31 Mha, 0.019 PgC, 0.006 PgC, and 0.025 PgC respectively.

30. Chhabra, A., K. R. Manjunath, S. Panigrahy and J. S. Parihar (2009). **"Spatial pattern of methane emissions from Indian livestock."** Current Science **96**(5): 683-689.

Methane is an important greenhouse gas that contributes to global warming, and livestock is a major anthropogenic source of methane emission from agriculture. India possesses the world's largest livestock population of 485 million. Among the livestock categories, cattle dominate with 38.2% followed by goat (25.7%), buffalo (20.2%), sheep (12.7%) and others (3.3%). The detailed state/district-level methane emission inventory by age-groups, indigenous and exotic breeds of different livestock categories was estimated using the country-specific and Indian feed standardbased emission coefficients and recent livestock census 2003. The total methane emission from Indian livestock, which includes enteric fermentation and manure management, was 11.75 Tg for 2003. Enteric fermentation accounts for 10.65 Tg (~91%) compared to 1.09 Tg (~9%) by manure management. Dairy buffalo and indigenous dairy cattle together contribute 60% of the total methane emission. The three high methane emitter states are Uttar Pradesh (14.9%), **Rajasthan** (9.1%) and Madhya Pradesh (8.5%). The detailed district-level spatial analysis in GIS environment resulted in the identification of clusters of districts with high emissions. Among these, Mednipur District (West Bengal) reported the highest total methane emission of 0.12 Tg. Using the remote sensing-derived livestock available feed/fodder area, the average methane flux from Indian livestock was computed as 74.4 kg/ha. [Uttar Pradesh, **Rajasthan** and Andhra Pradesh are the top three States with 58.5, 49.1 and 48.2 million total livestock population, respectively. Among the districts, Mednipur (West Bengal) leads with highest cattle and

buffalo population of 3.54 million, followed by Jhalawar (**Rajasthan**) with 2.7 million. Uttar Pradesh, **Rajasthan** and Madhya Pradesh are three high methane emitter States, with a contribution of 1.75 Tg (14.9%), 1.07 Tg (9.1%) and 1.00 Tg (8.5%) respectively.]

31. Chowdhury, S. P., M. Schmid, A. Hartmann and A. K. Tripathi (2009). "**Diversity of 16S-rRNA and nifH genes derived from rhizosphere soil and roots of an endemic drought tolerant grass, *Lasiurus sindicus*.**" European Journal of Soil Biology **45**(1): 114-122.

Lasiurus sindicus is a highly nutritive, drought tolerant, perennial grass, endemic to the Thar Desert of Rajasthan, India. This study provides evidence that *L. sindicus* harbors a diversity of bacteria with potential for nitrogen fixation.

32. Das, K. and P. Sharma (2007). "**Potable water for the rural poor in arid Rajasthan: Traditional water harvesting as an option.**" Journal of Rural Development **26**(1): 1-22.

Traditional water harvesting systems (TWHS), generally neglected, have come to be recognised as an important source of potable water, especially in the arid and semi-arid regions of India. This paper enquires into the potential of wells (as TWHS) in the Thar desert area of Rajasthan. Following a detailed analysis of hydrological and structural aspects of the source and quality of water, the paper presents results of intensive field surveys conducted in two villages in the districts of Jodhpur and Barmer. Given the pattern of water use and dependence upon alternative sources for drinking and domestic purposes, the households' willingness to pay for reviving/modernising TWHS and piped system has heen analysed in comparison. An important insight gained is that desilting and developing local surface water sources, although more expensive so far as capital cost is concerned, is preferable over piped water supply from elsewhere. While very poor households would, naturally, decline to share the capital costs for an improved water system, their willingness to contribute labour and O & M costs suggested value attached by the local community to TWHS as sustainable sources of potable water in arid regions, at least.

33. Dash, S. K., M. A. Kulkarni, U. C. Mohanty and K. Prasad (2009). "**Changes in the characteristics of rain events in India**." J. Geophys. Res. **114**: D10109, doi:10110.11029/12008JD010572.

Daily gridded (1° × 1°) rainfall data prepared by the India Meteorological Department for the period 1951–2004 have been used in this study to examine possible changes in the frequency of rain events in India in terms of their duration and intensity per day.

So far as the duration is concerned, a rain event is classified as short, long, dry, or prolonged dry spell. Similarly in terms of intensity, a rainy day is considered as low, moderate, or heavy. Results show that the frequencies of moderate and low rain days considered over the entire country have significantly decreased in the last half century. On the basis of the duration of rain events it is inferred that long spells show a significant decreasing trend over India as a whole while short and dry spells indicate an increasing tendency with 5% significance. The characteristics of rain events are also examined over six homogenous rainfall zones separately since the spatial distribution of rainfall over India shows large variability. In this study, the changes in the frequencies of different categories of rain events suggest weakening of the summer monsoon circulation over India.

34. Dash, S. K., R. K. Jenamani, S. R. Kalsi and S. K. Panda (2007). "**Some evidence of climate change in twentieth-century India**." Climatic Change **85**(3): 299-321.

The study of climate changes in India and search for robust evidences are issues of concern especially when it is known that poor people are very vulnerable to climate changes. Due to the vast size of India and its complex geography, climate in this part of the globe has large spatial and temporal variations. Important weather events affecting India are floods and droughts, monsoon depressions and cyclones, heat waves, cold waves, prolonged fog and snowfall. Results of this comprehensive study based on observed data and model reanalyzed fields indicate that in the last century, the atmospheric surface temperature in India has enhanced by about 1 and 1.1°C during winter and post-monsoon months respectively. Also decrease in the minimum temperature during summer monsoon and its increase during post-monsoon months have created a large difference of about 0.8°C in the seasonal temperature anomalies which may bring about seasonal asymmetry and hence changes in atmospheric circulation. Opposite phases of increase and decrease in the minimum temperatures in the southern and northern regions of India respectively have been noticed in the interannual variability. In north India, the minimum temperature shows sharp decrease of its magnitude between 1955 and 1972 and then sharp increase till date. But in south India, the minimum temperature has a steady increase. The sea surface temperatures (SST) of Arabian Sea and Bay of Bengal also show increasing trend. Observations indicate occurrence of more extreme temperature events in the east coast of India in the recent past. During summer monsoon months, there is a decreasing (increasing) trend in the frequency of depressions (low pressure areas). In the last century the frequency of occurrence of cyclonic storms shows increasing trend in the month of November. In

addition there is increase in the number of severe cyclonic storms crossing Indian Coast. Analysis of rainfall amount during different seasons indicate decreasing tendency in the summer monsoon rainfall over Indian landmass and increasing trend in the rainfall during pre-monsoon and post-monsoon months.

35. Deotare, B. C., M. D. Kajale, S. N. Rajaguru, S. Kusumgar, A. J. T. Jull, J. D. Donahue. (2004). "**Palaeoenvironmental history of Bap-Malar and Kanod playas of western Rajasthan, Thar desert**." Proceedings of the Indian Academy of Sciences-Earth and Planetary Sciences **113**(3): 403-425.

Two playas in the arid core of the western margin of the **Thar Desert** viz., Bap-Malar and Kanod, have been investigated using palynology, geomorphology, archaeology, AMS-radiocarbon dating, stable isotopes, evaporite mineralogy and geoarchaeology. The principal objective was to obtain a reliable lithostratigraphy of the playa sediments. These are about 7 m thick in the Bap-Malar and > 2.5 to 3 m thick in the Kanod. AMS C-14 dates of > 15 ka BP on pollen from sediment layers indicates that the Bap-Malar playa possibly existed even during the LGM. These playas were full of water during the early Holocene (8 ka BP - 5.5 ka BP) and were ephemeral during the Pleistocene-Holocene transition and early to mid to late Holocene. The playas dried almost 1000 years earlier than those occurring on the eastern margin. Pollen of graminaceae, henopodiaceae/amaranthaceae, cyperaceae etc. and evaporite minerals like gypsum, halite in the profiles indicate that the playas were surrounded by vegetation dominated by grass and that, they remained brackish to saline even during the mid Holocene, lake full stage. Stable dune surfaces, pediments with regoliths, and gravelly channels of ephemeral streams provided a favorable geomorphic niche for nomadic human activity since similar to 7 ka BP. Though local ecological factors have played an important role in the evolution of the playas, the winter rains, connected with northwesterly depressions, most likely played a vital role in maintaining these playas.

36. Dhir, R. P., A. K. Singhvi, J. E. Andrews, A. Kar, B. K. Sareen, S. K. Tandon, A. Kailath and J. V. Thomas (2010). "**Multiple episodes of aggradation and calcrete formation in Late Quaternary aeolian sands, Central Thar Desert, Rajasthan, India**." Journal of Asian Earth Sciences **37**(1): 10-16.

A 12 m thick section in a dune-sandy plain terrain of the Central Thar in **Rajasthan**, has provided a near continuous record of environmental change for the past 160 ka. The site presently receives 280 mm rainfall, almost entirely from the summer monsoon. The base of this section comprises a gravel bed of an ephemeral stream

and the overlying six litho-units, each with discrete boundaries, comprise a succession of aeolian sands. Luminescence dating provided an estimate of the timing of the sand aggradation periods to 160, 90, 60, 27 and 17–14 ka and helped constrain the timing of calcrete formation periods. In each aggradation unit, discrete nodular calcretes formed by the leaching of carbonate from the overlying solum. This is analogous to present-day conditions in sandy plains during periods of increased rainfall and landscape stability. Several of these calcretes are, however, devoid of their donor solum, suggesting solum removal during a subsequent period of decreased rainfall and resultant surface instability. This is supported by the presence of reworked nodules on the surfaces of some calcretes. A prominent phase of calcrete development followed the aeolian sand aggradation at 60 ka, suggesting climate amelioration that also caused the formation of groundwater-related calcrete and mottling. The study suggests that stage II calcrete nodules form in a time frame of 10–20 ka, and confirms limited data on the duration and stage of calcrete development in the literature. The $\delta^{13}C$ values of calcrete carbonate lie in a narrow range (+0.5 to −1.1‰) suggesting formation under soils with C_4 vegetation. This implies that even during phases of climatic amelioration, the high temperatures and increased seasonality of rainfall did not permit significant development of C_3 plants in the Central Thar.

37. Enzel, Y., L. L. Ely, S. Mishra, R. Ramesh, R. Amit, B. Lazar, S. N. Rajaguru, V. R. Baker, A. Sandler. (1999). "**High-resolution Holocene environmental changes in the Thar desert, northwestern India**." Science **284**: 125-128.

Sediments from Lunkaransar dry lake in northwestern India reveal regional water table and lake level fluctuations over decades to centuries during the Holocene that are attributed to changes in the southwestern Indian monsoon rains. The lake levels were very shallow and fluctuated often in the early Holocene and then rose abruptly around 6300 carbon-14 years before the present (^{14}C yr B.P.). The lake completely desiccated around 4800 ^{14}C yr B.P. The end of this 1500-year wet period coincided with a period of intense dune destabilization. The major Harrapan-Indus civilization began and flourished in this region 1000 years after desiccation of the lake during arid climate and was not synchronous with the lacustral phase… This drying phase precedes by 800 to 1000 years the rise of the Early and Mature Harappan phases of the Indus civilization from 4100 to 3500 ^{14}C yr B.P. (2600 to 2000 B.C.). This contradicts the climate-culture hypothesis for northwestern India and Pakistan. Improved climatic conditions did not lead to the rise of this major urban civilization, as has been suggested. The collapse of the Indus

culture in 3400 to 3300 ^{14}C yr B.P. (1700 to 1900 B.C.) has been attributed to a change to a more arid climate at the end of the middle Holocene wet period. The chronology indicates that there is no relation between the proposed drought that caused the desiccation of the lakes and the collapse of the Indus culture, as the lakes dried out >1500 years earlier. The wet climate-Indus civilization relationship was previously challenged, but it remains a prime example of a climate-civilization relationship]. The Indus civilizations flourished mainly along rivers during times when northwestern India experienced semiarid climatic conditions that are similar to those at present.

38. Fleitmann, D., S. J. Burns, M. Mudelsee, U. Neff, J. Kramers, A. Mangini, and A. Matter. (2003). "**Holocene forcing of the Indian monsoon recorded in a stalagmite from southern Oman**." Science **300**(5626): 1737-1739.

A high-resolution oxygen-isotope record from a thorium-uranium-dated stalagmite from southern Oman reflects variations in the amount of monsoon precipitation for the periods from 10.3 to 2.7 and 1.4 to 0.4 thousand years before the present (ky B.P.). Between 10.3 and 8 ky B.P., decadal to centennial variations in monsoon precipitation are in phase with temperature fluctuations recorded in Greenland ice cores, indicating that early Holocene monsoon intensity is largely controlled by glacial boundary conditions. After ~8 ky B.P., monsoon precipitation decreases gradually in response to changing Northern Hemisphere summer solar insolation, with decadal to multidecadal variations in monsoon precipitation being linked to solar activity.

39. Garg, A., R. C. Dhiman, S. Bhattacharya and P. R. Shukla (2009). "**Development, malaria and adaptation to climate change: A case study from India**." Environmental Management **43**(5): 779-789.

Over 650 million people in India depend on climate-sensitive sectors, such as rain-fed agriculture and forestry, for livelihood and over 973 million people are exposed to vector borne malarial parasites. Projection of climatic factors indicates a wider exposure to malaria for the Indian population in the future. If precautionary measures are not taken and development processes are not managed properly some developmental activities, such as hydro-electric dams and irrigation canal systems, may also exacerbate breeding grounds for malaria. This article integrates climate change and developmental variables in articulating a framework for integrated impact assessment and adaptation responses, with malaria incidence in India as a case study. The climate change variables include temperature, rainfall,

humidity, extreme events, and other secondary variables. Development variables are income levels, institutional mechanisms to implement preventive measures, infrastructure development that could promote malarial breeding grounds, and other policies. The case study indicates that sustainable development variables may sometimes reduce the adverse impacts on the system due to climate change alone, while it may sometimes also exacerbate these impacts if the development variables are not managed well and therefore they produce a negative impact on the system. The study concludes that well crafted and well managed developmental policies could result in enhanced resilience of communities and systems, and lower health impacts due to climate change. [In 2003 in **Rajasthan**, a large epidemic affecting several districts had occurred. It is projected that 10% more states will have transmission windows open for all the 12 months as compared to the year 2000 malaria scenario. The transmission windows in northern states of Jammu and Kashmir and the western state of **Rajasthan** are likely to increase by 3–5 months.]

40. Gessler, M., U. Brighu and R. Franceys (2008). **"The challenge of economic regulation of water and sanitation in urban India."** Habitat International **32**(1): 49-57.

The water and sewerage sector seems to be most reluctant to join the reform process as numerous attempts at privatisation have failed and economic regulation has yet to be introduced. Through comparisons with the electricity sector, this study considers how economic regulation might challenge the public providers of water in Jaipur, **Rajasthan** and possible effects on the needs for water and sanitation of the poorest. The picture drawn from Jaipur's water utility portrays inefficiencies, lack of customer involvement and representation, a haphazard pro-poor water policy and consequently a strong need for reforms. Given the present reluctance for private sector involvement and now regulation in water and sanitation sector, it is recommended that the public water utilities in India should identify improvements that can actually be implemented without significant institutional change for example non-revenue water reduction, leakage reduction, optimize energy use by asset management planning and bringing down the cost of production, transmission and distribution along with the above mentioned reforms. However this is easier said than done, looking at the huge population and the poor record keeping. Hence it is suggested that instead of trying to adopt a institutional reform process, a piecemeal approach be taken and simultaneously the middle income group be taken into confidence through their political representatives, balancing local service improvements with local tariff raise.

41. Gleick, P. H., R. M. Adams, R. M. Amasino, E. Anders, D. J. Anderson, W. W. Anderson, L. E. Anselin, M. K. Arroyo, B. Asfaw, F. J. Ayala, A. Bax, A. J. Bebbington, G. Bell, M. V. L. Bennett, J. L. Bennetzen, M. R. Berenbaum, O. B. Berlin, P. J. Bjorkman, E. Blackburn, J. E. Blamont, M. R. Botchan, J. S. Boyer, E. A. Boyle, D. Branton, S. P. Briggs, W. R. Briggs, W. J. Brill, R. J. Britten, W. S. Broecker, J. H. Brown, P. O. Brown, A. T. Brunger, J. Cairns, Jr., D. E. Canfield, S. R. Carpenter, J. C. Carrington, A. R. Cashmore, J. C. Castilla, A. Cazenave, F. S. Chapin, III, A. J. Ciechanover, D. E. Clapham, W. C. Clark, R. N. Clayton, M. D. Coe, E. M. Conwell, E. B. Cowling, R. M. Cowling, C. S. Cox, R. B. Croteau, D. M. Crothers, P. J. Crutzen, G. C. Daily, G. B. Dalrymple, J. L. Dangl, S. A. Darst, D. R. Davies, M. B. Davis, P. V. de Camilli, C. Dean, R. S. Defries, J. Deisenhofer, D. P. Delmer, E. F. Delong, D. J. Derosier, T. O. Diener, R. Dirzo, J. E. Dixon, M. J. Donoghue, R. F. Doolittle, T. Dunne, P. R. Ehrlich, S. N. Eisenstadt, T. Eisner, K. A. Emanuel, S. W. Englander, W. G. Ernst, P. G. Falkowski, G. Feher, J. A. Ferejohn, A. Fersht, E. H. Fischer, R. Fischer, K. V. Flannery, J. Frank, P. A. Frey, I. Fridovich, C. Frieden, D. J. Futuyma, W. R. Gardner, C. J. R. Garrett, W. Gilbert, R. B. Goldberg, W. H. Goodenough, C. S. Goodman, M. Goodman, P. Greengard, S. Hake, G. Hammel, S. Hanson, S. C. Harrison, S. R. Hart, D. L. Hartl, R. Haselkorn, K. Hawkes, J. M. Hayes, B. Hille, T. Hokfelt, J. S. House, M. Hout, D. M. Hunten, I. A. Izquierdo, A. T. Jagendorf, D. H. Janzen, R. Jeanloz, C. S. Jencks, W. A. Jury, H. R. Kaback, T. Kailath, P. Kay, S. A. Kay, D. Kennedy, A. Kerr, R. C. Kessler, G. S. Khush, S. W. Kieffer, P. V. Kirch, K. Kirk, M. G. Kivelson, J. P. Klinman, A. Klug, L. Knopoff, H. Kornberg, J. E. Kutzbach, J. C. Lagarias, K. Lambeck, A. Landy, C. H. Langmuir, B. A. Larkins, X. T. Le Pichon, R. E. Lenski, E. B. Leopold, S. A. Levin, M. Levitt, G. E. Likens, J. Lippincott-Schwartz, L. Lorand, C. O. Lovejoy, M. Lynch, A. L. Mabogunje, T. F. Malone, S. Manabe, J. Marcus, D. S. Massey, J. C. McWilliams, E. Medina, H. J. Melosh, D. J. Meltzer, C. D. Michener, E. L. Miles, H. A. Mooney, P. B. Moore, F. M. M. Morel, E. S. Mosley-Thompson, B. Moss, W. H. Munk, N. Myers, G. B. Nair, J. Nathans, E. W. Nester, R. A. Nicoll, R. P. Novick, J. F. O'Connell, P. E. Olsen, N. D. Opdyke, G. F. Oster, E. Ostrom, N. R. Pace, R. T. Paine, R. D. Palmiter, J. Pedlosky, G. A. Petsko, G. H. Pettengill, S. G. Philander, D. R. Piperno, T. D. Pollard, P. B. Price, Jr., P. A. Reichard, B. F. Reskin, R. E. Ricklefs, R. L. Rivest, J. D. Roberts, A. K. Romney, M. G. Rossmann, D. W. Russell, W. J. Rutter, J. A. Sabloff, R. Z. Sagdeev, M. D. Sahlins, A. Salmond, J. R. Sanes, R. Schekman, J. Schellnhuber, D. W. Schindler, J. Schmitt, S. H. Schneider, V. L. Schramm, R. R. Sederoff, C. J. Shatz, F. Sherman, R. L. Sidman, K. Sieh, E. L. Simons, B. H. Singer, M. F. Singer, B.

Skyrms, N. H. Sleep, B. D. Smith, S. H. Snyder, R. R. Sokal, C. S. Spencer, T. A. Steitz, K. B. Strier, T. C. Sudhof, S. S. Taylor, J. Terborgh, D. H. Thomas, L. G. Thompson, R. T. TJian, M. G. Turner, S. Uyeda, J. W. Valentine, J. S. Valentine, J. L. van Etten, K. E. van Holde, M. Vaughan, S. Verba, P. H. von Hippel, D. B. Wake, A. Walker, J. E. Walker, E. B. Watson, P. J. Watson, D. Weigel, S. R. Wessler, M. J. West-Eberhard, T. D. White, W. J. Wilson, R. V. Wolfenden, J. A. Wood, G. M. Woodwell, H. E. Wright, Jr., C. Wu, C. Wunsch and M. L. Zoback (2010). **"Climate change and the integrity of science."** Science **328**(5979): 689-690.

There is compelling, comprehensive, and consistent objective evidence that humans are changing the climate in ways that threaten our societies and the ecosystems on which we depend. Many recent assaults on climate science and, more disturbingly, on climate scientists by climate change deniers are typically driven by special interests or dogma, not by an honest effort to provide an alternative theory that credibly satisfies the evidence. The Intergovernmental Panel on Climate Change (IPCC) and other scientific assessments of climate change, which involve thousands of scientists producing massive and comprehensive reports, have, quite expectedly and normally, made some mistakes. When errors are pointed out, they are corrected. But there is nothing remotely identified in the recent events that changes the fundamental conclusions about climate change: (i) The planet is warming due to increased concentrations of heat-trapping gases in our atmosphere. A snowy winter in some parts of the world does not alter this fact. (ii) Most of the increase in the concentration of these gases over the last century is due to human activities, especially the burning of fossil fuels and deforestation. (iii) Natural causes always play a role in changing Earth's climate, but are now being overwhelmed by human-induced changes. (iv) Warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle. Rising concentrations of carbon dioxide are making the oceans more acidic. (v) The combination of these complex climate changes threatens coastal communities and cities, our food and water supplies, marine and freshwater ecosystems, forests, high mountain environments, and far more. Society has two choices: We can ignore the science and hide our heads in the sand and hope we are lucky, or we can act in the public interest to reduce the threat of global climate change quickly and substantively. Authors note that the good news is that smart and effective actions are possible. But delay must not be an option. Authors urge policy-makers and the public to move forward immediately to address the causes of climate change, including the unrestrained burning of fossil fuels.

42. Gosain, A. K., S. Rao and D. Basuray (2006). "**Climate change impact assessment on hydrology of Indian river basins**." Current Science **90**(3): 346-353.

The study has revealed that under the GHG scenario the conditions may deteriorate in terms of severity of droughts in some parts of the country and enhanced intensity of floods in other parts of the country. However, there is a general overall reduction in the quantity of the available runoff under the GHG scenario. Luni with the west-flowing rivers Kutch and Saurastra which occupies about one fourth of the area of Gujarat and 60 per cent of the area of **Rajasthan** shall face acute water scarce conditions. River basins of Mahi, Pennar, Sabarmati and Tapi shall also face water shortage conditions.

43. Goswami, B. N., V. Venugopal, D. Sengupta, M. S. Madhusoodanan and P. K. Xavier (2006). "**Increasing trend of extreme rain events over India in a warming environment**." Science **314**(5804): 1442-1445.

Against a backdrop of rising global surface temperature, the stability of the Indian monsoon rainfall over the past century has been a puzzle. By using a daily rainfall data set, authors show (i) significant rising trends in the frequency and the magnitude of extreme rain events and (ii) a significant decreasing trend in the frequency of moderate events over central India during the monsoon seasons from 1951 to 2000. The seasonal mean rainfall does not show a significant trend, because the contribution from increasing heavy events is offset by decreasing moderate events. A substantial increase in hazards related to heavy rain is expected over central India in the future.

44. Goswami, P. and K. V. Ramesh (2008). "**The expanding Indian desert: Assessment through weighted epochal trend ensemble**." Current Science **94**(4): 476-480.

One of the biggest challenges in climate research is to arrive at reliable future projections. However, numerical climate models still suffer from large uncertainties. Authors adopt a weighted epochal trend ensemble approach to assess the stability of the Indian desert with increased reliability. Ensemble techniques have generally helped to reduce uncertainties in forecasts and the weighted epochal trend ensemble proposed here takes into account the inherent nonlinearity in the trend by considering a piece (epoch)-wise linear trend and its weighted contributions to construct more reliable future projections of local climate change. It is first shown that epochal trend ensemble provides better estimates of future projections by comparing

observed rainfall over India during 1990-2003 with rainfall projected from a simple linear trend and an epochal trend ensemble. Authors then compute projections of desert area over India based on annual rainfall and show that the **Thar Desert** in western India is expanding in an eastward as well as northeast direction. Both the simple linear trend and the epochal trend ensemble projections indicate significant increase in the desert area over India over the next 100 years; however, there are also significant differences between the two projections. The results of the validation are used to choose the more reliable projection, which shows a sharp increase in the size of the Indian desert in the next hundred years.

45. Goyal, R. K. (2004). "**Sensitivity of evapotranspiration to global warming: a case study of arid zone of Rajasthan (India)**." *Agricultural Water Management* **69**(1): 1-11.

The change in climate is likely to have a profound effect on hydrological cycle viz. precipitation, evapotranspiration, soil moisture etc. In the present study, an attempt has been made to study the sensitivity of evapotranspiration to global warming for arid regions of **Rajasthan** (India). The study suggests an increase of 14.8% of total ET demand with increase in temperature by 20% (maximum 8 °C). ET is less sensitive (11%) to increase in net solar radiation, followed by wind speed (7%) in comparison to temperature. Increase in vapor pressure (20%) has a small negative effect on ET (−4.31%). A 10% increase in temperature and actual vapor pressure coupled with 10% decrease in net solar radiation could result even in marginal decrease of total ET (0.30%). Increase of 10% in temperature alone, with 10% decrease in net solar radiation, actual vapor pressure and wind velocity could also result in marginal decrease in total ET (0.36%). Long-term changes in evapotranspiration demand can have profound implications for the arid zone of Rajasthan. Even as small as 1% increase in temperature from base data could result in an increase in evapotranspiration by 15 mm, which means an additional water requirement of 34.275 mcm for Jodhpur district alone and 313.12 mcm for whole arid zone of Rajasthan. The total available surface water resources of the arid zone are to the tune of 1361.21 mcm. Although analysis of 100-year rainfall data for the arid region of Rajasthan indicates an increasing trend of 0.5 mm/year, but increased evapotranspiration demand due to global warming can put tremendous pressure on existing overstressed water resources of this region. Since this region is devoid of any perennial river system, any increase in water demand requires careful planning for future water resource development in this region. More emphasis is needed to develop technologies for reducing water losses in reservoirs, conservation of rainwater and development of crop varieties

requiring less water. A marginal increase in ET demand due to global warming will have a larger impact on resource-poor, fragile arid zone ecosystem of **Rajasthan**. It is high time for planners/users to think in terms of expected change in water requirement due to global warming while planning for development of future water resources in the arid region of **Rajasthan**.

46. Grove, R. H. (1998). "**Global impact of the 1789-93 El Niño**." Nature **393**: 318 – 319.

It has been suggested that global warming has caused the El Niño/Southern Oscillation (ENSO) climatic events to become more frequent and intense. However, several ENSO events that occurred before 1880 had effects at least as intense and wide-ranging as those associated with the current event. This is the case particularly for the events in 1396, 1685-88, 1789-93 and 1877-79. Here author discusses archival evidence, notably from South Asia and above all for the 1789-93 ENSO, for the strength of these historical effects. In peninsular India, every major drought between 1526 and 1900 has been closely associated with the eastern Pacific El Niño. The 1789-93 ENSO event produced prolonged droughts, especially in South Asia, a region where the association between ENSO and the monsoon is well established. This evidence that the 1789-93 ENSO had a strong global impact indicates that it was one of the most severe on record. As with the 1685-88 ENSO, the early stages of the 1789-93 event were observable in southern India more than a year before the El Niño effect was recorded in the Pacific basin. However, a few ENSO events, including the present event of 1997-98, coincide with a failure of the Southeast Asian monsoon rather than that of South Asia. In the case of the 1789-93 ENSO event, the monsoon failed in both regions. So the developmental sequence of the 1789-93 ENSO is important as a basis for comparison with other, very severe, ENSO events.

47. Gundimeda, H. (2004). **"How 'sustainable' is the 'sustainable development objective' of CDM in developing countries like India?"** Forest Policy and Economics **6**(3-4): 329-343.

The rural poor and landless require resilient, sustainable livelihood systems that are flexible in the short term due to dependence on multiple products. The Kyoto Protocol requires that Clean Development Mechanism (CDM) projects result in long-term benefits related to the mitigation of climate change. This long-term requirement to keep carbon in storage may conflict with the short-term needs of the poor. Based on the analysis, the paper concludes that for CDM to be sustainable and result in sustainable development of the local people, three important criteria should be satisfied: (1)

Integrating the energy substitution possibilities in the objectives of carbon sequestration; (2) Management of the CPR lands by the rural poor through proper design of the rules for sustenance of user groups; and (3) Ensuring that the maximum revenue from carbon sequestration is channelled to the rural poor. Otherwise CDM would just result in either leakage of carbon benefits or have negative welfare implications for the poor.

48. Gupta, A. K. (2004) **"Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration."** Current Science **87**(1): 54-59.

Domestication of plants and animals was necessary for the evolution of agriculture, spatial expansion and population increase of humans during the Holocene, which facilitated the evolution of technically innovative societies. The agricultural practices enabled people to establish permanent settlements and expand urban-based societies. Domestication of plants and animals transformed the profession of the early humans from hunting and gathering to selective hunting, herding and settled agriculture. The earliest archaeological evidences, found throughout the tropical and subtropical areas of southwestern and southern Asia, northern and central Africa and Central America, suggest rapid and large-scale domestication of plants and animals ca. 10,000-7000 cal years BP. This interval corresponds to an intense humid phase and equable climates, as observed in numerous paleo records across the regions. Domestication of plants and animals and subsequent beginning of agriculture were linked to climate amelioration in the early Holocene.

49. Gupta, A. K., D. M. Anderson, and J. T. Overpeck. (2003). **"Abrupt changes in the Asian southwest monsoon during the Holocene and their links to the North Atlantic Ocean."** Nature **421**(6921): 354-357.

During the last ice age, the Indian Ocean southwest monsoon exhibited abrupt changes that were closely correlated with millennial-scale climate events in the North Atlantic region, suggesting a mechanistic link. In the Holocene epoch, which had a more stable climate, the amplitude of abrupt changes in North Atlantic climate was much smaller, and it has been unclear whether these changes are related to monsoon variability. Here authors present a continuous record of centennial-scale monsoon variability throughout the Holocene from rapidly accumulating and minimally bioturbated sediments in the anoxic Arabian Sea. Monsoon proxy record reveals several intervals of weak summer monsoon that coincide with cold periods documented in the North Atlantic region--including the most recent climate changes from the Medieval Warm Period to the Little

Ice Age and then to the present. Authors detect continued variability in monsoon intensity, including a shift from strong to weak monsoon during the transition from the Medieval Warm Period (AD 800–1300) to the Little Ice Age (AD 1300–1870). Authors suggest that the link between North Atlantic climate and the Asian monsoon is a persistent aspect of global climate.

50. Gupta, A.K., Anderson, D.M., Pandey, D.N., Singhvi AK. (2006). "**Adaptation and human migration, and evidence of agriculture coincident with changes in the Indian summer monsoon during the Holocene**". Current Science **90**(8): 1082-1090.

Human societies have evolved through a complex system of climate and ecological interactions. Known records suggest intimate relationship of adaptations, mitigations and migrations to climate extremes leaving their im- pacts on human societies. The northwestern part of India provides such an example, where human civilizations flourished in the early Holocene along the major fluvial systems when the Indian summer (southwest) monsoon was much stronger and rainfall was higher over the Indian land mass. In **Rajasthan**, northwestern India, the vegetational history documents a shift towards arid phase since 4200 cal yrs BP. Summers were thus wetter, conducive to agriculture and ecodiversity. Changes in the early civilizations in the Indian subcontinent had a close relation to changes in the monsoon climate over the past 10,000 years. The summer monsoon has weakened over the last 7000 years since its peak intensification in the early Holocene (10,000-7000 cal yrs BP). Discrete intervals of dry phases in the summer monsoon are visible in the proxy record of the monsoon winds from the marine sediments of the Arabian Sea, which had significant impact on human settlements in South Asia. The strongest aridity in the Indian subcontinent and extended periods of droughts at ca 5000-4000 cal yrs BP seems to have triggered eastward human migrations towards the Ganga plain. Other times of monsoon weakening during the Holocene are coincident with the initial development of ponds, reservoirs and other rainwater harvesting structures that may have served as an adaptation to climate change.

51. Gupta, A. K., S. Sarkar, S. De, S. C. Clemens, and A. Velu (2010), **Mid-Brunhes strengthening of the Indian Ocean Dipole caused increased equatorial East African and decreased Australasian rainfall.** Geophysical Research Letters **37**: L06706, doi:10.1029/2009GL042225.

The tropical Indian Ocean is an important component of the largest warm pool, marked by changes in sea surface temperatures and depths of thermocline and mixed layer in its western and eastern

extremities leading to the development of a dipole mode - the Indian Ocean Dipole (IOD). A narrow band of westerlies (7°N to 7°S) sweep the equatorial Indian Ocean during the April–May and October–November transitions between the summer- and winter-monsoon seasons. These Indian Ocean equatorial westerlies (IEW) are closely related to the IOD, intensifying the upper ocean Eastward Equatorial current also known as Wyrtki jets. The strength of the IOD/IEW determines the moisture content in East Africa. A major decrease in the strength of the IEW (strengthening or positive mode of the IOD) during the mid-Brunhes epoch (~300–250 Kyr BP) coincides with a wetter equatorial East Africa, a drier Australasia and a stronger Indian summer monsoon, indicating that the IOD/IEW play a significant role in driving climate change in East Africa, Australasia and South Asia.

52. Gupta, G. N. (1994). **"Influence of rain water harvesting and conservation practices on growth and biomass production of *Azadirachta indica* in the Indian desert."** Forest Ecology and Management **70**(1-3): 329-339. A field experiment was conducted to investigate the influence of various rain water harvesting and conservation techniques on soil moisture storage, growth and biomass production of *Azadirachta indica* (neem) in the Indian desert. The treatments were as follows: control; weed removal; weed removal plus soil working; saucers of 1.0 m diameter; saucers of 1.5 m diameter; saucers of 1.5 m diameter covered with mulch around the trees; bunding around each tree in a checkerboard design; inter-row slopes of 20%. The treatment with inter-row slopes of 20% produced the highest amount of soil moisture storage, a four times increase in total biomass of a 26-month-old neem plantation (from 1.69 to 6.39 t ha^{-1}), a 4.5 times increase in root mass (from 0.43 to 1.92 t ha-1) and a 70% increase in tree height, as well as an appreciable enhancement in all the growth parameters. The treatment with larger saucers (1.5 m diameter) combined with a surface mulch was equally effective. Growth increases owing to the other water harvesting treatments were lower, though significantly better when compared with the control. The various treatments significantly improved the water use efficiency of neem.

53. Gupta, G. N. (1995). **"Rain-water management for tree planting in the Indian Desert."** Journal of Arid Environments **31**(2): 219-235. A field experiment was conducted at the Arid Forest Research Institute, Jodhpur to study the influence of different systems of water harvesting and moisture conservation on soil moisture storage, growth, biomass accumulation and nutrient uptake by *Azadirachta indica* (neem), *Tecomella undulate* (rohida) and *Prosopis cineraria* (kherjri). The ridge and furrow method of water harvesting

was found to be the best treatment and significantly improved their growth of three species (height by 58%, 35% and 40%, collar circumference by 73%, 56% and 63%, and crown diameter by 111%, 51%, and 131%, respectively). Biomass accumulation by *A. indica* and *T. undulate* increased 3·8-fold and 4·6-fold and root mass 4·5-fold and 3·8-fold, respectively. The mulching treatment was beneficial to *A. indica* and weeding treatment to all the three species. Trees roots in water harvesting plots were deeper and had several times larger spread than the control. Nutrient uptake by these tree species increased several-folds as a result of the different water harvesting and moisture conservation treatments. The increase in cost of plantation due to T_8 treatment was 50%.

54. Gupta, G. N., N. K. Limba and S. Mutha (1999). **"Growth of *Prosopis cineraria* on microcatchments in an arid region."** Annals of Arid Zone **38**(1): 37-44.

The influence of different in situ water harvesting structures (microcatchments) on establishment and growth of *Prosopis cineraria* (khejri) was studied on a flat sandy aridisol. Water harvesting structures included 45 × 45 × 45 cm pits (control), saucer pit having 2.5 m diameter; ring pit, trench cum mound, trench and mound and deep ploughing + pitting. Trees attained highest growth in ring pit followed by trench and mound and saucers after 57 months of planting. Biomass production from tree prunings was 6-9 times higher in ring pits, trench and mound and saucers as compared to the control. Plant survival improved from 30% in the control to 86-97% in these microcatchments. Soil moisture storage was 39-51% higher in ring pit, trench and mound and saucers as compared to the control. Since the cost of planting in ring pits was 60% higher than in the control, adoption of trench and mound structures and saucers is recommended which cost respectively, 21% and 27% more than the control.

55. Gupta, G. N., S. Mutha and N. K. Limba (2000). **"Growth of *Albizia lebbeck* on microcatchments in the Indian arid zone."** Forests Trees and Livelihoods **10**(3): 193-202.

A field experiment was conducted to determine the growth rates of *Albizia lebbeck* (siris) grown under different methods of micro-catchment water harvesting in the Indian arid zone. Six microcatchment water harvesting treatments were: control (only pitting), saucers of 2.5 m diameter, ringpits, trench-cum-mound, trench and mound and deep ploughing. The five water harvesting treatments were associated with significant increases in height and collar girth of Albizia lebbeck, compared to the control. Twenty-one months after planting, trees were 2.3 times taller in ringpits and two

times taller in saucers and trench and mound than the control (P=0.001; F=9.8). Eighteen months after planting basal girth was 3.3, 3.0 and 3.8-fold higher, respectively in T3, T2 and T5 treatments than the control, (P=0.000; F=13.8). With advancing age of plantation, growth differences between the control and the above treatments decreased. Fifty four months after planting, the most growth was attained by the trees in ringpits (446 ± 25 cm height and 36.7 ± 4.3 cm girth) followed by saucers (422 ± 11 cm height and 35.3 ± 1.2 cm girth) and trench and mound (427 ± 36 cm height and 32.7 ± 2.0 cm girth), compared to 284 ± 54 cm height and 23.7 ± 5.3 cm girth in the control. Ringpits and trench and mound structures resulted in 50 % higher soil water storage in the upper 75 cm layer, compared to the control (P=0.000; F=12.99). Plant survival improved from 50% in the control to 92 to 97% in microcatchments. Biomass yield of pruned material was higher in ringpits, trench and mound and saucers by 12 to 20 times, compared to the control. Since the cost of planting in ringpits was 60% higher than in the control, adoption of trench and mound structures and saucers, which cost 21% and 27% higher compared to the control, is recommended. These structures could be made under drought and famine relief works, which are quite common under Desert Development programmes. The technique will provide useful employment and a source of livelihood to people, besides increasing wood production and green cover.

56. Gupta, J. P. and A. K. Sharma (1998). **"Integrated effect of water harvesting and manuring on growth and establishment of *Prosopis cineraria* (Khejri) in hot-arid region of Rajasthan."** Indian Forester **124**(1): 54-58.

Scarcity of water during tree establishment can be overcome by making circular catchment around the tree seedling. Integration of treatments viz. catchment area and farm yard manure was done to test the increase in profile moisture and ultimately increase in survival and growth of *Prosopis cineraria*, an important multipurpose tree of desert ecosystems. The results of the field experiment showed that after 36 months of planting there was a four fold increase in plant height with catchment area of 12.6 m^2 as compared to control. Farm Yard Manure (FYM) was not found effective statistically. Also no interaction effect was observed in the different combination of the levels of both the two factors i.e. catchment size and FYM application.

57. Gupta, R. K. (1968). **"Anthropogenic influences on the vegetation of Western Rajasthan."** Vegetatio **16**(1): 79-94.

Western **Rajasthan**, forming a part of the **Thar desert**, is admittedly dry, very hot in summer and is generally poor in

vegetation. Though various causes for the origin of this desert have been attributed by climatologists, geographers and geologists, based on anthropological evidences it seems that there has been severe destruction of vegetation during the past. Over this landscape was superimposed the present day conditions, mainly the human influences, direct and indirect, on the vegetation, thus making the conditions still arid. From the observations it is seen that the water table in tube wells in some villages is good, patches of good density of vegetation are present where managed properly or dedicated to some deity. The rainfall, though scanty, is sufficient to support vegetation and if some rest is given the climax is reached especially where the nucleus exists. Though climatically the area is dry but not arid, soils are poor but not infertile and evidence is said to be there that in the past it supported good evergreen vegetation. Immediate establishment of vegetation, even on active sand dunes, can be seen even today if an area is protected rigidly from human and animal influences. During drought periods there may not be any augmentation of vegetation, yet those already established live, stabilise the soil and perpetuate the progress of vegetation. With protection not only the grasses and rank vegetation come up but even species like *Prosopis cineraria* come up. It may therefore be said that **Rajasthan** desert, if not a "man made desert" is surely a "man maintained desert".

58. Gupta, R. K. (1971). "**Ecology of pastoral areas in the arid zone of Rajasthan**." Annals of Arid Zone **10**(2/3): 136-137.

Literature on area, land use and climate of pastoral areas of arid W. **Rajasthan** is reviewed. Grasslands are clssified according to drought resistance into 4 categories: ephemeral drought evading, perennial drought evading, perennial drought resistant, and perennial drought resistant semi-succulent type. The distribution of the main grassland types in relation to climate and soil and the relationship between grasslands, animal population and stocking rate are discussed. Suggestions for collecting data on consumers of the native vegetation and soil decomposers to achieve a better understanding of the range ecosystem in the arid regions of **Rajasthan** are given.

59. Gupta, S. K. and R. D. Deshpande (2004). "**Water for India in 2050: first-order assessment of available options**." Current Science **86**(9): 1216-1224.

Water resources of India are examined in the context of the growing population and the national ambition to become and be seen as a developed nation. The population of India is expected to stabilize around 1640 million by the year 2050. As a result, gross per capita water availability will decline from ~ 1820 m^3/ yr in 2001 to as

low as ~1140 m^3/yr in 2050. Total water requirement of the country for various activities around the year 2050 has been assessed to 1450 km^3/yr. This is significantly more than the current estimate of utilizable water resource potential (1122 km^3/yr) through conventional development strategies. Therefore, when compared with the availability of ~ 500 km^3/yr at present, the water availability around 2050 needs to be almost trebled. It is argued that due to considerations of gestation period and capital requirements, rainwater harvesting and water-conservation measures must receive the highest priority followed by renovation and recycling to be followed by intra- and then inter-basin transfers in the last phase. But, investigations and planning processes for all options must begin immediately.

60. Gupta, S. S. and R. C. Verma (1993). **"Stabilization of farm income and employment under water scarcity conditions."** Annals of Arid Zone **32**(3): 183-186.

This study was conducted in Naga-Ki-Dhani village in Jaipur district, **Rajasthan**, India. Four optimum crop plans to stabilize farm income and employment during drought years were developed using linear programming techniques. The results of the optimum plans showed that use of improved varieties of crops developed specifically for water scarcity conditions, would increase farm income. However, available working capital during drought years would not enable full use of whatever little irrigation water was available in the open wells, and hence credit availability to farmers in drought years is crucial.

61. Henderson, C. E. (1989). **"Life in the land of death: famine and drought in arid western Rajasthan."** Dissertation Abstracts International. A, Humanities and Social Sciences **50**(5): pp.1349-1350.

This research examines adjustment and adaptation to frequent drought in **Rajasthan**'s **Thar Desert** and the ways in which economic stratification, community organization, and links to outside regions promote or hinder survival. These data provide a basis for examining the impact of external economic ties on vulnerability to drought, as hypothesized in earlier works on famines in India. The research, based on fieldwork conducted in a village of India's **Thar Desert** in 1981/82 when the rains failed for the third consecutive year, indicates that resistance to drought varies according to the resource base of households. A household's wealth is positively associated with its structure and ability to diversify production into the three components of crops, livestock and outside work migration. The risk of failure is also reduced through the use of actual and fictional kin relationships which facilitate access to resources outside the village. Beyond their positive functional value, these adaptations t o drought suggest that the area is integrated into a broad set of

economic and political relationships centred on market relations for the sale of livestock products and urban wage- labour. The ability to exploit these opportunities is unequally experienced by different wealth groups and in turn leads to economic differentiation based more on inequality of access than on intracommunity wealth transfers.

62. Hiremath, R. B., B. Kumar, P. Balachandra, N. H. Ravindranath and B. N. Raghunandan (2009). "**Decentralised renewable energy: Scope, relevance and applications in the Indian context.**" Energy for Sustainable Development **13**(1): 4-10.

Presently used centralised energy planning model ignores energy needs of rural areas and poor and has also led to environmental degradation, whereas decentralised energy planning model is in the interest of efficient utilisation of resources. Energy planning at the village level is the bottom limit of the application of decentralised planning principle. The individual villages are the smallest social units where the energy consumption occurs. Renewable energy is energy derived from sources that are being replaced by nature, such as water, wind, solar or biomass. Renewable sources are essentially non-polluting if applied correctly. The paper presents a review of the important decentralised renewable energy options, related case studies of successful deployment of renewable energy technologies in India and resulting lessons learnt. Case studies discussed in the present work show the feasibility of decentralised energy options for the residential and small scale applications in a village or a cluster of villages. The paper also details the different initiatives taken by the government of India to promote decentralised energy production in India. It is found that the small scale power generation systems based on the renewable energy sources are more efficient and cost effective. Thus the focus should be on the small scale renewable energy technologies that can be implemented locally by communities and small scale producers, but can make a significant overall contribution towards the national energy supply.

63. Huq, S., Yamin, F., Rahman, A., Chatterjee, A., Xiu, Y., Wade, S., Orindi, V. and J. Chigwada (2005). "**Linking climate adaptation and development: a synthesis of six case studies from Asia and Africa**." IDS Bulletin **36**(4): 117-122.

Increased temperature, floods, droughts, extreme events and changes in precipitation pose additional risks for developing countries and vulnerable communities striving to alleviate poverty and to achieve sustainable development. Knowledge and experience of adapting to climatic conditions has been built up over a millennia by communities in many parts of the world, including developing

countries, often on the basis of experimentation initiated by communities. This synthesis brings together the main insights and conclusions from case studies describing examples of successful community-led interventions in six countries: China, India, Bangladesh, Senegal, Kenya and Zimbabwe. The climate impacts studied include extreme events, such as national floods, and quieter forms of climatic disaster such as long-term aridity/drought, temperature increase and wind-related land degradation. The synthesis examines the roles played by formal and informal institutions, policy champions, donors, knowledge and research in decreasing vulnerabilities and supporting community-led adaptation to climate change.

64. Jain, M. and S. K. Tandon (2003). **"Fluvial response to Late Quaternary climate changes, western India**." Quaternary Science Reviews **22**(20): 2223-2235.

Authors review the fluvial response to Late Quaternary climatic changes in the semi-arid regions of western India, i.e. the **Thar Desert** and its margins, and Maharashtra. The rivers in the **Thar Desert** show a spectrum of environments from gravel bedload braided to ephemeral sand-bed streams to sheet flows and sheet floods, while those in the Thar margin and Maharashtra show dominantly two modes, i.e. braided and meandering rivers. The streams became defunct and aeolian sands were deposited during periods of relatively greater aridity in the **Thar Desert** and its margins. Incisions occurred during the wet phases. It is inferred that changes in the monsoon precipitation led to relative changes in the discharge and sediment supply, which were routed through those in the vegetation cover, and played a key role in determining the fluvial style. An inter-comparison of the Late Quaternary alluvial deposits in the semi-arid regions of western India suggests a continuum of fluvial environments interrelated through a precipitation gradient. Further, a global comparison indicates that the response of semi-arid western Indian rivers was synchronous with the rivers in other climatic settings.

65. Jain, S. K., R. Keshri, A. Goswami, A. Sarkar and A. Chaudhry (2009). **"Identification of drought-vulnerable areas using NOAA AVHRR data."** International Journal of Remote Sensing **30**(10): 2653-2668.

Drought is a recurring phenomenon in many parts of India, bringing significant water shortages, economic losses and adverse social consequences. The western regions of India (**Rajasthan** and Gujarat provinces) have suffered with severe droughts several times in the past. In this study meteorological and satellite data were used

for monitoring drought in the southern part of **Rajasthan**. Authors found that in 2002 all of the area under study was affected by drought with greater intensity, mostly classed as extreme and severe drought conditions.

66. Jat, M. L., R. Singh, B. S. Kumpawat, J. K. Balyan. (2003). "**Rainy season and its variability for crop planning in Udaipur region**." Journal of Agrometeorology **5**(2): 82-86.

Rainy season and its variability in Udaipur region, **Rajasthan**, India have been studied for the period 1981-2000. The study reveals that off-season tillage and primary tillage may be started from 24th week and sowing of crop from 26th week. Occurrences of two consecutive dry weeks were analysed using Markov-Chain model. Mid-season drought is likely in 31st-34th week and terminal drought in the 35th week in the region.

67. Jodha, N. S. (1975). "**Famine and famine policies: some empirical evidence**." Economic and Political Weekly **10**(41): 1609-1623.

The famine relief policies of the Indian government have been criticised for being too liberal, wasteful and devoid of any economic rationality. It has been argued by scholars that the lack of understanding by the administrators of the true nature of the distress caused by drought or famine is responsible for these deficiencies. The validity of these criticisms is examined, using empirical evidence from the arid region of Western **Rajasthan**, one of the drought prone areas in India. The study concludes that ignorance about the true nature of distress on the part of administrators is not an important factor responsible for the deficiencies of famine policies. Lack of economic rationality in famine policies is ascribed to the generalized distortions of the system.

68. Jodha, N. S. (1985). "**Population growth and the decline of common property resources in Rajasthan, India.**" Population & Development Review **11**(2): 247-264.

Using data from villages in three districts of Western **Rajasthan**, describes the decline in area and deterioration in quality of common property resources over three decades. The decline of common property resources is associated with institutional changes in the villages. The introduction of land reforms in the early 1950s led to large scale privatization of common property resources, reduced the private cost of use of common property resources, and slackened their upkeep by disrupting the traditional management system. Increased commercialization of livestock farming, increased use of tractors, and demographic pressure also played roles in the process.

Farmers adjusted to shrinking common property resources by reducing herd size, by changing its compositon, and by relying more on private resources to rear animals. These changes tend to reduce the comparative advantage of livestock farming in the arid region. Since the shrinkage of common property resources is largely a result of the transfer of submarginal lands from grazing to cropping, resource degradation is accelerated.

69. Jodha, N. S. (1988). "**Farmers adjustment strategies against rainfall variability in dry regions of India**." Fertiliser News **33**(4): 67-72.

The paper presents: (1) the differences in structural and operational features of farming systems in areas with different degrees of weather risk, to indicate farmers' adaptations to the long-term behaviour of rainfall; (2) differences in cropping decisions in response to different soil moisture situations during the planting season at the same locations, to illustrate adjustment measures against inter-year differences in seasonal rainfall; (3) differences in input use and farm practices during drought year and normal rainfall year at the same locations, to indicate the degree of flexibility and short-term adjustments to serious deficit in rainfall; and (4) differences in households' non-crop decisions and actions during drought year and non-drought year, to illustrate another aspect of adjustment to weather risk. The areas studied are Akola and Sholapur in Maharashtra, and Jodhpur in **Rajasthan**.

70. Joseph, G. (1997). "**Role of remote sensing in resource management for arid regions with special reference to western Rajasthan.**" Current Science **72**(1): 47-54.

The arid region of western **Rajasthan** is about 20.87 Mha covering 85 blocks of 12 districts of Rajasthan which constitutes 61% of the state. About 38% of the total population of the state with a density of 84 persons per sq km area lives in the arid region of Rajasthan. The constantly increasing human and livestock population is putting tremendous pressure on the available natural resources. The major problems of the region are: scarcity of water, frequent droughts, land degradation, deteriorating pasture lands and advancement of desert. Therefore, it is essential to explore newer sources of resources as well conserve the existing natural resources. Optimal management of natural resources is of utmost importance in today's context to increase the production of food grains, fodder and develop water resources for meeting the demand. Remote sensing provides timely, reliable and spatially comprehensive data on various natural resources for effective planning, implementation and monitoring.

71. Kafle, N. and J. Mathur (2009). "**Feasibility study of capturing carbon credit benefits in an academic institution: A case study**." Energy and Buildings **41**(1): 133-137.

The CDM potential in an academic institution hosting 2500 students is analyzed through the introduction of renewable energy technologies (Solar Water Heater, Solar Steam Cooking) and adoption of energy efficient technologies (Compact Fluorescent Lighting, Energy Efficient Air Conditioners). The baseline emission has been calculated for each technology. A detail investment analysis has been carried out for each of these measures. The impact of revenue generated by selling carbon credits through the clean development mechanism (CDM), on the economic viability of the project activity is analyzed along with sensitivity analysis. Out of the four cases analyzed, energy efficient lighting and energy efficient air conditioners do not require CDM benefits for their viability hence they fail to prove the additionality. Solar steam cooking having negative value of IRR does not pass the additionality criterion for CDM. The solar water heater generating 48.13 tCO_2/year is identified as the candidate CDM project. The total amount of CO_2 that can be saved from emitting to the atmosphere by employing the renewable and energy efficient technologies is 311.34 tCO_2/year. The CERs generated by this project are insufficient to cover the validation/ verification and registration expenses. For converting the CDM potential into reality, bundling of the similar activities with nearby academic institutes can be considered.

72. Kajale, M. D. and B. C. Deotare. (1997). "**Late Quaternary environmental studies on salt lakes in western Rajasthan, India: a summarised view**." Journal of Quaternary Science **12**(5): 405 – 412.

The paper reviews pollen analytical and palaeoenvironmental work carried out on saline lakes in western **Rajasthan**, northwest India. The saline lakes are salient geomorphological features within the arid and semi-arid landscapes to the west of the Aravalli mountain ranges. Preliminary palynological work was carried out on two profiles from a gypsum-rich lake depression around Thob (District of Barmer). The varied pollen data are indicative of a fluctuating vegetational assemblage, possibly in response to local hydrological conditions and not necessarily indicative of climatic change. Pollen of *Ephedra* sp. (a typical desert species) in the lower levels suggests episodes of relatively dry conditions during the early phase of lake sedimentation at the end of the Pleistocene. Other work at four lake sites, on the basis of pollen analysis has indicated shifts in climatic and vegetational belts during the early Holocene,

especially during the period of Indus Valley Culture. Later in the Holocene, between 5000 and 3500 yr BP, rainfall variations have been related to the dynamics of the monsoon. Pioneering geoarchaeological studies carried out at the palaeolithic site of 16 R and the adjacent Didwana lake have illustrated palaeoclimatic fluctuations and accompanying changes in cultural stages from the lower palaeolithic to mesolithic. These studies have been extended geochemically and sedimentologically through a detailed study documenting a history of salinity from 20000 to 13000 yr BP and freshwater conditions from 9000 to 6000 yr BP. Later studies have illustrated a sequence of changes reflecting summer and winter precipitation. These have indicated steppe vegetation during the last Glacial Maximum along with hypersaline lake conditions at Didwana, inferring a weakened summer monsoon and relatively high winter precipitation. The taxa indicative of both summer and winter precipitation in the mid-Holocene declined during the late Holocene, at the same time as falling lake levels around 4000 yr BP, a time when other lakes, at Sambhar, Lunkaransar and Pachpadra, also became ephemeral.

73. Kakade, B., K. Petare, G. Neelam, S. Pawar, A. Chaurasia. (2003). **"Combating drought through a participatory watershed development approach: a case study from Gokulpura-Govardhanpura villages in Bundi district, Rajasthan, India."** Natural Resource Management **6**(2): 2-11.

Most of **Rajasthan** falls under the hot, semiarid agroclimatic zone. With 5.017 million ha of cultivable wasteland, the State of **Rajasthan** bears the highest share from a total of 13.879 million ha for India. The yield of food grains in the State is only 803 kg per hectare and is the lowest for any state in India. Droughts are ubiquitous to **Rajasthan**, with erratic rainfall and extreme temperatures being common features in many areas. This paper presents the approach implemented in the Bundi district. The implementation of the holistic watershed development approach has been suggested.

74. Kala, M. and A. Sharma (2010). **"Traditional Indian beliefs: a key toward sustainable living."** The Environmentalist **30**(1): 85-89.

India is known for the moral ethos of its people. Indian beliefs have been associated with compassion and respect for nature and its creations since ages. In **Rajasthan**, a desert state of India, the Khejri tree is valued for its moisture-retaining properties, and it is not axed even if it comes between the constructions. The live example of this is cited in Salasar Balaji temple in Sikar district. A Bishnoi cult of India inhabiting the Jodhpur region is known for wildlife protection

specially the famous Black Buck that is an endangered species. Some areas popularly known as sacred groves or orans that are dedicated to a local deity worshipped by the inhabitants of that area are especially reserved for biodiversity conservation, and anthropogenic activities are completely prohibited. These examples show that traditional beliefs of Indian societies have got a deeper understanding of the ecological system and have been completely integrated with nature to evolve sustainable lifestyle.

75. Kale, V. S., A. K. Singhvi, P. K. Mishra, D. Banerjee. (2000). "**Sedimentary records and luminescence chronology of Late Holocene palaeofloods in the Luni River, Thar Desert, northwest India**." CATENA **40**(4): 337-358.

River Luni is the only well-integrated river system in the **Thar Desert** of India. This river catastrophically flooded due to unusually heavy rainfall in the catchment area during July 1979. In order to establish whether floods of this magnitude have occurred in the recent geological past, sedimentary records of palaeofloods occurring in the Sindari Gorge, in the lower Luni Basin were investigated. The principal slackwater flood deposits were observed in a back-flooded tributary near Bhuka. Analysis of the slackwater flood deposits preserved in the back-flooded tributary and their luminescence dating suggests that the Luni River has experienced at least 17 extreme floods during the past millennium. Evidence from the Bhuka site also suggests that no floods comparable in magnitude to the July 1979 megaflood have occurred during this period. This observation is in conformity with the palaeoflood record of central India. Comparison of the long-term monsoon rainfall series for the Luni Basin and the Indian region reveals a clear link between the two, and indicates that the clustering of large floods in the last few decades and during the Medieval warming period is a regional phenomenon associated with wetter conditions. This correlates with a regionally extended episode of landscape stability denoted by stabilization of dunes in this region.

76. Kalra, N., D. Chakraborty, A. Sharma, H. K. Rai, M. Jolly, S. Chander, P. R. Kumar, S. Bhadraray, D. Barman, R. B. Mittal, M. Lal and M. Sehgal (2008). "**Effect of increasing temperature on yield of some winter crops in northwest India**." Current Science **94**(1): 82-88.

The effect of increase in temperature on grain yield of some winter crops (wheat, mustard, barley and chickpea) in northwest India was evaluated on the basis of historic records and through a dynamic crop growth model, WTGROWS. The optimal date of sowing was also evaluated in view of the increase in seasonal temperature. The yield of these crops, especially wheat, already

showing signs of stagnation in most places of northwest India, is most likely to be affected by temperature changes. The solar radiation-temperature interactions study in wheat reveals some interesting trends and is seen to vary from one location to another. Keeping in view the trends in global climate change, a shift in sowing time, as an adaptation strategy is recommended. The simple and empirical relations between yield and seasonal temperature change can be well used for a crude estimate of yield dependence of temperature rise of these winter crops. Attainable yield of wheat is also subject to decrease with similar degree of increase in temperature. Yield–temperature response curves show that there is a decrease in grain yield of wheat in all the four states studied, with maximum decrease in Haryana (4.29 q per ha) followed by **Rajasthan** (2.49 q per ha) per degree rise in seasonal temperature. For mustard, the maximum decrease in grain yield was noticed in Haryana where the grain yield decreased by 2.01 q per ha per degree rise in seasonal temperature, whereas decrease of 0.98 and 0.92 q per ha in grain yield was observed in UP and **Rajasthan** respectively. On the response of barley and chickpea: The maximum decrease here also was observed in Haryana, where grain yield decreased by about 5.01 q per ha per degree rise in seasonal temperature. The grain yield decreased by 2.71, 1.94 and 1.64 q per ha per degree rise in temperature, in Punjab, **Rajasthan** and UP respectively.

77. Kar, A. (2009). "**Wind erosion potentials in the Thar-Megathar region from AD 1951 to 2100: Patterns and implications.**" Abstract in International conference on Nurturing Arid Zones for People and The Environment: Issues and Agenda For The 21st Century, November 24-28, 2009, CAZRI, Jodhpur, Rajasthan, India, pp. 24-25.

Thar Desert, lying at the eastern end of the Indo-Saharan hot desert belt of low-latitude, is a dominantly monsoon driven sand desert where wind erosion is a major problem during the summer months of March to July. In order to better understand the role of wind strength and other natural drivers in spatiotemporal variability in wind erosion features and aeolian bedforms in the desert, Kar (1993) had prepared a scale of wind erosion index and a map of mean annual erosivity for Thar Desert, which was based on an inverse relationship between the cube of monthly average wind velocity and precipitation effectiveness of Thornthwaite for March to July, and relied on the normal (1931-60) station data from IMD for arid areas in India and Pakistan. The annual wind erosion index was calculated as the sum of the values from March to July and was calibrated between very low (index value 1-14) and extremely high (index value 480 and above). The map explained the features of aeolian

perturbations very well. It was shown that the sandy areas to the west of 120 contour were most vulnerable to wind erosion/deposition, while such areas between 120 and 30 contours were moderately to slightly vulnerable, unless there was very high human pressure. Very high wind erosion and higher concentration of mobile dunes were shown to exist in areas with 480 or higher index values. Using global gridded data of atmospheric parameters, authors show here for the first time the yearly variation in wind erosion index (WED in different sub-zones of the Thar Desert and its past maximum extension, called the Megathar (1951-2000), as well as the likely scenario for the Twenty-first Century (5- yearly mean from 2001 to 2100). Author also discusses the relationship of erosivity with land surface dryness and dust emission. Since the study involved accessing data across nations, the gridded data were accessed from GPCC, IPCC, UK-HMO, NCEP-NCAR, DKRZ-ECHAM, EU-ERA40, Willmott and Matsuura, etc., and randomly tested for consistency with the available IMD data for Indian part. Additionally a number of satellite-derived products on rainfall, temperature, NDVI and dust emission (e.g., from AVHRR, MODIS, TOMS, MISR, TRMM, SPOT, etc.) were perused. All the data were processed and integrated in a GIS environment for mapping and analysis. Calculations based on precipitation data from GPCC-V ASClimo, temperature, precipitation and evaporation data from Willmott & Matsuura (both at 0.512spatial grid) and wind speed data from ECHAM5 simulations for the 20th century (ECHAM5-20C.3M-All; -1.8712spatial grid) explained the erosivity during the second half of the Twentieth Century satisfactorily. This is despite the fact that contouring of the mean wind speed (March to July) for 1951-80 from ECHAM5 simulation yielded slightly lower values than the contoured values from station data for the Indian part of the desert (IMD data).

These results show that during the 1950s the spatial average of WEI was 30-50 per cent higher than the mean for the 1951-2000 period in all the sub-zones except in Megathar-east where it was almost at per with the 50-year mean. Since then Megathar-west has experienced less erosivity than the 50-year mean, while Megathar-south has seen 45 per cent higher erosivity during the 1980s, but less than the 50-year mean in other decades. Other suP-zones experienced 2-18 per cent higher erosivity than the 50-year mean during the 1960s, and 20-40 per cent lower erosivity during the1970s. The 1980s, which saw the 4-year long drought throughout the region, experienced up to 20 per cent higher erosivity, followed in the 1990s by 10-40 per cent fall from the 50-year mean. We then attempted to link the WEI in different sub-zones with the dust emission signatures (TOMS AI) for 1979 to 2000 (with a data gap from 1993 to 1996). It showed good correspondence between the two variables till the mid-1990s, but a

new instrument since 1997 recorded steep increase in AI despite a falling wind strength and variable rainfall, and perhaps reflected a greater control of critical land use changes in the sandy terrain through tractor use and expansion of cropland. Nevertheless, good correspondence between the two variables in earlier periods suggests the possibility of using WEI as a surrogate for the spatial pattern of dust emission, at least under natural conditions.

For the Twenty-first Century we chose to visualize the pattern in five-yearly averages and under A2 scenario. Author first mapped the simulated precipitation and temperature data for 2001-2005 from some of the available models and matched them with the pattern from ground observation data. Author found the ECHAM5-AR4 simulation data more appropriate. Additionally we calculated WEI for 5-yearly blocks from 1951 to 2000 using ECHAM5-20C-3M data, and regressed the spatial pattern on previously calculated pattern, which revealed tolerable correlation between the two datasets, except for 1951-55, and strengthened the selection. These results show that during the present century mean WEI was at its lowest in all the subdivisions of the Thar and the Megathar during 2001-05, except in the Megathar-east that will possibly see its lowest mean during 2011-15. Between 1951 and 2100 the lower mean WEI values were recorded during 1991-95 and 1996-2000, except in Megathar-north where the trends in the mean values are mostly out of phase with the trends in other subdivisions. Between 2016 and 2030 mean WEI is likely to be very high in all the subdivisions of the Thar and the Megathar, equaling or surpassing the earlier peaks of 1961-65 and 1986-90. Although the erosivity is expected to decline slightly in 2031-35, it may gradually increase again from 2036-40, attaining a peak in the middle of the century, followed by a series of high-magnitude changes to the end of the century. In between, 2071-75 will probably see a major fall in mean WEI in all the subdivisions, tending to match the values of 2001-05. We expected a synchrony between WEI and surface dryness, but it was not always so, suggesting a complex relationship between the variables. Wind strength is expected to increase steadily over the decades. Broadly, the above trends is expected to sharply increase the atmospheric dust load in the region from 2016-20, which may get accelerated if the present groundwater-dependent irrigation system collapses, because large-scale clearance of natural vegetation, expansion of the cropland and deep ploughing of sandy land took place in the wake of irrigation. This has already lowered the WEI values for wind erosion areas from 120 to ~30. Much more effort in land-conservation practices would, therefore, be required than at present to stabilize the aeolian bedforms, both in the Indian part and the Pakistan part of the desert.

78. Kar, A. (1986). "**Physical environment, human influences and desertification in Pushkar: Budha Pushkar lake region of Rajasthan, India**." The Environmentalist **6**(3): 227-232.

The hazard of desertification is now threatening one of the most celebrated and sacred lake regions in India, the Pushkar — Budha Pushkar region, which is situated within the Aravallis, in **Rajasthan**. While, on the basis of known climatic records and physical potentiality of the land, secular change of climate can be ruled out as a possible cause for the present situation, the location of the zone along the fringe of the desert, and its inherent vulnerable nature due to its terrain characteristics, are more important factors for consideration. A lack of understanding of the type of responses of the terrain to indiscriminate biotic activities, and a reluctance to take any measure to stabilize the ecosystem by people resident in the area, have resulted in destruction of the natural vegetation, accelerated the movement of sand from the formerly well-stabilized dunes and sandy plains, and deteriorated the lake environment. However, such destructive trends could still be reversed through well planned programmes of afforestation, soil and water conservation, and people's supportive participation.

79. Kar, A., A. K. Singhvi, S. N. Rajaguru, N. Juyal, J. V. Thomas, D. Banerjee, R. P. Dhir. (2001) "**Reconstruction of the late Quaternary environment of the lower Luni Plains, Thar Desert, India**." Journal of Quaternary Science **16**(1): 61-68.

Geomorphological processes in the **Thar Desert** of India are largely climate driven. In the lower reaches of the River Luni (the only major drainage system in the **Thar Desert**) a fluvio-aeolian sequence was located at a site called Khudala. Sediments of this sequence represented a variety of depositional environments, namely aeolian, fluvially reworked aeolian, overbank deposits, gravels, and occasional evidence of pedogenesis. This provided a good opportunity to study aeolian-fluvial interaction in the region and for deducing climatic records. From the luminescence dating standpoint these sequences offered a good opportunity for a comparative study of thermoluminescence (TL), blue-green light stimulated luminescence (BGSL) and infrared light stimulated luminescence (IRSL) on different mineral separates of identical provenance but deposited under different environments. Broadly, within experimental errors, the TL ages agreed with BGSL and IRSL ages on aeolian sands, but differed substantially in the case of fluvially reworked and proximally deposited sands and silts. The sequence provided a record spanning more than 100 ka, with an aeolian phase at > 100 ka, a channel activation phase between 70 and 30 ka and a

phase of climate instability between 13 and 8 ka. This appears consistent with the records of monsoon performance during this period, which includes the Younger Dryas. It is also inferred that during the Last Glacial epoch, geomorphological processes in the Thar (both aeolian and fluvial) were dormant largely on account of their relationship with the southwest monsoon.

80. Kashyap, A. (2004). **"Water governance: learning by developing adaptive capacity to incorporate climate variability and change."** Water Science & Technology **49**(7): 141-6.

There is increasing evidence that global climate variability and change is affecting the quality and availability of water supplies. Integrated water resources development, use, and management strategies, represent an effective approach to achieve sustainable development of water resources in a changing environment with competing demands. It is also a key to achieving the Millennium Development Goals. It is critical that integrated water management strategies must incorporate the impacts of climate variability and change to reduce vulnerability of the poor, strengthen sustainable livelihoods and support national sustainable development. UNDP's strategy focuses on developing adaptation in the water governance sector as an entry point within the framework of poverty reduction and national sustainable development. This strategy aims to strengthen the capacity of governments and civil society organizations to have access to early warning systems, ability to assess the impact of climate variability and change on integrated water resources management, and developing adaptation intervention through hands-on learning by undertaking pilot activities.

81. Kaul, M., V. K. Dadhwal and G. M. J. Mohren (2009). **"Land use change and net C flux in Indian forests."** Forest Ecology and Management **258**(2): 100-108.

Using the IPCC 2006 guidelines for greenhouse gas inventories this paper reports on the net carbon flux caused by deforestation and afforestation in India over the period from 1982 to 2002, separately for two time periods, 1982–1992 (PI) and 1992–2002 (PII. The approach accounts for forest and soil C pool changes for (a) forest areas remaining as forests, (b) afforested areas and (c) deforested areas. The data set used were remote sensing based forest cover for three time periods (1982, 1992, 2002), biomass increments, biomass expansion factors and wood density. In the 1982–2002 period, the forest cover changed from 64.20 Mha in 1982 to 63.96 and 67.83 Mha in 1992 and 2002 respectively. During the PI and PII periods, plantations were also established of 0.2 and 0.5 Mha yr^{-1}, while the annual deforestation rate was about 0.22 and 0.07 Mha in

these periods, respectively. The average net flux of carbon attributable to land use change decreased from a source level of 5.65 Tg C yr^{-1} (or 0.09 Mg C ha^{-1} yr^{-1}) during PI (1982–1992) to a sink level of 1.09 Tg C yr^{-1} (or 0.02 Mg C ha^{-1} yr^{-1}) during PII (1992–2002). Over recent years, Indian forests have acted as a small carbon sink. The results indicate that the conversion of land to forest (regeneration/afforestation) led to a net uptake of 0.86 and 1.85 Tg C yr^{-1} in PI and PII, respectively. By contrast, the net C emissions from the forest land conversion to another land use (deforestation) resulted in annual emissions of 9.9 and 3.2 Tg C during PI and PII, respectively. The cumulative net carbon flux from Indian forests due to land use change between 1982 and 2002 was estimated as 45.9 Tg C. The largest fluxes result from the conversion of forest land to cropland and waste lands, and since there are uncertainties in input variables (due to very large spatial heterogeneity) that affect net C flux from land use change, there is an urgent need for more reliable district-based data to facilitate accurate and refined estimates in future.

82. Kelley, T. G., P. Parthasarathy Rao, E. Weltzien R and M. L. Purohit (1996). **"Adoption of improved cultivars of pearl millet in an arid environment: Straw yield and quality considerations in western Rajasthan."** Experimental Agriculture **32**(2): 161-171.

The role of straw yield and quality in farmers' decisions about the adoption of pearl millet cultivars in western **Rajasthan** was examined using farm household surveys. Information on the relative importance of grain versus straw yield, the perceived risks associated with the use of new cultivars under variable climatic conditions and perceptions of straw quality indicated that improved cultivars of pearl millet were not adopted primarily because of poor grain yield in years with low rainfall, though poor straw yield in such years was also important. These results are particularly pertinent in the light of farmers' perceptions of the likelihood of experiencing drought or low rainfall. If new cultivars of pearl millet are to replace the traditional ones, they must perform better under conditions of limited rainfall.

83. Khanna, R. K., R. S. Rathore and C. Sharma (2008). **"Solar still an appropriate technology for potable water need of remote villages of desert state of India, Rajasthan."** Desalination **220**(1-3): 645-653.

Rajasthan, the largest state of the India faces a grim scenario in relation to water availability resources. **Rajasthan** has two-third of its area as desert and it faces scanty rainfall, recurring droughts in 3-4 years in a cycle of 5 years. It would be seen from the present status of drinking water detailed out of 237 blocks in **Rajasthan** that only 49

are safe in terms of ground water while 101 are critical and semi critical and 86 are over exploited. It is a hard reality that state dependence on ground water is 91% for drinking water. About 21,190 villages/habitations suffer from the problem of excessive salinity, 23,297 villages/habitations suffer from excess fluoride problem and 20,659 villages/habitations suffer from excess nitrate problem. Based on the WHO guidelines for drinking-water quality about 56% of the water sources are un-potable. But on other hand **Rajasthan** is blessed with ample amount of solar radiation. The arid parts of **Rajasthan** receive average maximum solar radiation of about 7.5 kW h/m² in the month of May and minimum of about 4.6 kW h/m² in the month of Dec & Jan. Part of this energy may be utilized to meet out drinking water need of remote area dwellers of **Rajasthan**. Solar distillation and desalination unit is most appropriate for remote area dwellers because it is economical, easy to construct and maintain. Most parts of **Rajasthan** have enough solar radiation available which is the prime input for the system. A low cost high efficiency solar still with porous evaporating surface is fabricated for the purpose and cost analysis is done to calculate the cost of water in this paper.

84. Kishtawal, C. M., D. Niyogi, M. Tewari, R. A. P. Sr and J. M. Shepherd (2010). **"Urbanization signature in the observed heavy rainfall climatology over India**." International Journal of Climatology http://dx.doi.org/10.1002/joc.2044

Authors assess the urbanization impacts on the heavy rainfall climatology during the Indian summer monsoon. While a number of studies have identified the impact of urbanization on local precipitation, a large-scale assessment has been lacking. This relation between urbanization and Indian monsoon rainfall changes is investigated by analyzing in situ and satellite-based precipitation and population datasets. Using a long-term daily rainfall dataset and high-resolution gridded analysis of human population, this study showed a significantly increasing trend in the frequency of heavy rainfall climatology over urban regions of India during the monsoon season. Urban regions experience less occurrences of light rainfall and significantly higher occurrences of intense precipitation compared to nonurban regions. Very heavy and extreme rainfall events showed increased trends over both urban and rural areas, but the trends over urban areas were larger and statistically more significant. The analysis suggests that there is adequate statistical basis to conclude that the observed increasing trend in the frequency of heavy rainfall events over Indian monsoon region is more likely to be over regions where the pace of urbanization is faster. Moreover, rainfall measurements from satellites also indicate that urban areas are more (less) likely to

experience heavier (lighter) precipitation rates compared to those in nonurban areas. While the mechanisms causing this enhancement in rainfall remain to be studied, the results provide the evidence that the increase in the heavy rainfall climatology over the Indian monsoon region is a signature of urban-induced rainfall anomaly.

85. Krishan, A., K. Jain and P. Tewari (1996). "**Indigenous architecture of two Indian deserts and modern climatic responsive solutions**." Renewable Energy **8**(1-4): 272-277.

This paper presents the climate responsive principles of architectural design evolved through time in the development of indigenous architecture. A scientific analysis of settlements at Leh (Ladakh) and Jaisalmer (**Rajasthan**) presents their appropriateness in terms of thermal performance. Principles of architectural design evolved in these settlements when applied to modern buildings, illustrated through two projects designed by the author, suggest how low energy architecture, that is, sustainable, can be developed in the modern context, basically by way of architectural design.

86. Krishnan, A., Y. S. Rama Krishna, and G. G. S. N. Rao. 1980. "**Is the incidence of droughts increasing in the arid zone of north-west India?**" In, H. S. Mann, (ed.) Arid Zone Research and Development. Scientific Publishers, Jodhpur, pp. pp. 47-51.

The occurrence of drought is studied through the determination of secular trends in the occurrence of deficit rainfall years, the available growing period, and moderate to severe drought periods as estimated by weekly water balances for the rainy season. Daily rainfall data from different stations in western **Rajasthan** from 1901-1970 were used. Deficit rainfall years occurred more frequently during 1901-1920 and 1961-1970. The decreasing trend in the 1961-1970 decade is well marked in zones where rainfall is less than 300 mm annually. Rainfall deficit weeks for 1901-1970 do not show any specific trend. In the recent decade (1961-1970), there was a slight decrease in the growth period and increase in the severe drought periods from the values of the previous decade.

87. Kumar, K. K., K. R. Kumar, R. G. Ashrit, N. R. Deshpande, J. W. Hansen. (2004). "**Climate impacts on Indian agriculture**." International Journal of Climatology **24**(11): 1375-1393.

Agriculture is highly dependent on the spatial and temporal distribution of monsoon rainfall. This paper presents an analysis of crop-climate relationships for India, using historic production statistics for major crops (rice, wheat, sorghum, groundnut and sugarcane) and for aggregate food grain, cereal, pulses and oilseed production. All-India annual total production (except sorghum and

sugarcane), and production in the monsoon (except sorghum) and post-monsoon seasons (except rice and sorghum) were significantly correlated to all-India summer monsoon rainfall. Monsoon season crops (except sorghum) were strongly associated with the three potential monsoon predictors. Results using state-level crop production statistics and subdivisional monsoon rainfall were generally consistent with the all-India results, but demonstrated some surprising spatial variations. Whereas the impact of subdivisional monsoon rainfall is strong in most of the country, the influence of concurrent predictors related to El Nino-southern oscillation and the Indian Ocean sea-surface temperatures at a long lead time seem greatest in the western to central peninsula.

88. Kumar, K. R., A. K. Sahai, K. K. Kumar, S. K. Patwardhan, P. K. Mishra, J. V. Revadekar, K. Kamala and G. B. Pant (2006). "**High-resolution climate change scenarios for India for the 21st century**." Current Science **90**(3): 334 - 345.

A state-of-art regional climate modelling system, known as PRECIS (Providing Regional Climates for Impacts Studies) developed by the Hadley Centre for Climate Prediction and Research, is applied for India to develop high-resolution climate change scenarios. The presentday simulation (1961–1990) with PRECIS is evaluated, including an examination of the impact of enhanced resolution and an identification of biases. The RCM is able to resolve features on finer scales than those resolved by the GCM, particularly those related to improved resolution of the topography. The most notable advantage of using the RCM is a more realistic representation of the spatial patterns of summer monsoon rainfall such as the maximum along the windward side of the Western Ghats. There are notable quantitative biases in precipitation over some regions, mainly due to similar biases in the driving GCM. PRECIS simulations under scenarios of increasing greenhouse gas concentrations and sulphate aerosols indicate marked increase in both rainfall and temperature towards the end of the 21st century. Surface air temperature and rainfall show similar patterns of projected changes under A2 and B2 scenarios, but the B2 scenario shows slightly lower magnitudes of the projected change. The warming is monotonously widespread over the country, but there are substantial spatial differences in the projected rainfall changes. West central India shows maximum expected increase in rainfall. Extremes in maximum and minimum temperatures are also expected to increase into the future, but the night temperatures are increasing faster than the day temperatures. Extreme precipitation shows substantial increases over a large area, and particularly over the west coast of India and west central India. [PRECIS estimates 20% rise in all India summer monsoon rainfall in

future scenarios as compared to present. Rise in rainfall is seen over all states except Punjab, **Rajasthan** and Tamil Nadu, which show slight decrease in precipitation in the future scenarios.]

89. Kumar, K. R., G. B. Pant, B. Parthasarathy and N. A. Sontakke (1992). "**Spatial and subseasonal patterns of the long-term trends of Indian summer monsoon rainfall**." International Journal of Climatology **12**(3): 257-268.

Long-term changes in the Indian monsoon rainfall on regional and local scales have important social and economic consequences. To present a comprehensive picture of such changes, the monthly rainfall data at 306 stations, well spread over India, have been analysed over 114 years (1871-1984), for long-term trends. The trends are quantified by linear trend for monthly as well as seasonal rainfall for each station. Some broad contiguous areas showing statistically significant trends have been identified. Areas of increasing trend in the monsoon seasonal rainfall are found along the west coast, north Andhra Pradesh and north-west India, and those of decreasing trend over east Madhya Pradesh and adjoining areas, north-east India and parts of Gujarat and Kerala. The subseasonal patterns indicate that the excess or deficiency of the monsoon rainfall is more frequently realized in the later half of the season. Monsoon rainfall tends to be more concentrated in August, over the west coast and central India.

90. Kumar, M. and M. M. Bhandari (1993). "**Human use of the sand dune ecosystem in the semiarid zone of the Rajasthan Desert, India.**" Land Degradation & Rehabilitation **4**(1): 21-36.

Sand dunes form one of the most fragile terrestrial ecosystems in Rajasthan where they have a diversity of vegetation and are often utilized by considerable human and livestock populations. A thorough knowledge of the resource utilization by the human and animal populations is essential if the future potential of the ecosystem and its physical stability under changing environmental conditions are to be accurately assessed. This study examines the socio-economic aspects of land degradation at four sites in Churu and Jhunjhunu districts, northwest **Rajasthan**. An attempt is made to assess the socio-economic factors leading to land degradation. Data on human use of the **Thar Desert** semiarid ecosystem were collected through individual interviews, group discussions and field measurements. The present exploitation of soil and vegetation resources, possible future biomass deficiency, its impact on sustainable development and role in land degradation are examined. As a result of overgrazing, the land productivity has decreased considerably. The annual fodder deficit values in the study area are enormous. Demand for fuelwood at all the study sites is increasing, yet available forests have already largely

been cut down. Use of cattle dung to supplement fuelwood during the summer dry season and in drought periods has been decreasing due to low fodder availability and high livestock mortality. Human numbers are increasing, and livestock numbers are also multiplying. Soil erosion and desertification will continue to increase during the next decade unless effective counter measures are undertaken.

91. Kumar, M. and R. Avinash (1993). **"Surface water resources and its utilisation for irrigation in Rajasthan."** Irrigation & Power Journal **50**(4): 143-146.

The Indian State of Rajasthan has a total geographical area of 342 lac ha which is 10.4% of total geographical area of the country. Out of this, 255 lac ha is culturable area. The internal surface water resource of the State is estimated as 15.86 MAF which is nearly 1.16% of the total 1356 MAF surface water resources of the country. In addition to State's internal water resources, 13 421 MAF of water has been allocated to **Rajasthan** under various inter-state agreements out of which 8.361 MAF water is being utilised and projects for utilising remaining water are under construction. Created surface water irrigation potential of the State from Major and Medium Irrigation Projects has increased from 3.20 lac ha in 1951 to 20.17 lac ha at the end of 1991-92.

92. Kumar, S. and L. Bhawani (2005). **"Managing child malnutrition in a drought affected district of Rajasthan: a case study."** Indian journal of public health. **49**(4): 198-206.

Rajasthan is the largest state in the country frequently affected by droughts. The year 2002 happened to be the fifth consecutive year of drought. Almost all districts of the State were hit by it. The district of Baran located in South-East of Rajasthan has 'Sahariya' tribal population concentrated in its Kishanganj and Shahabad blocks. Rapid nutritional assessment indicated very high prevalence of severe under weight (28.3%) and wasting (4.7%) amongst under five children. Nutrition Care Centres (NCC) were set up in selected villages to provide targeted feeding and care to these children as per WHO guidelines. Local 'Sahariya' community was involved to run these NCC. Intensive public education campaign was carried out to promote improved child caring practices and referral of malnourished children with complication to hospitals. Orientation of press and electronic media on factual details regarding the situation helped create an enabling environment to implement remedial measures. The impact of 'Nutrition Care Centres' assessed after six months was found to be positive in terms of reduction in prevalence of under nutrition in children from 66.7% to 59.6%. Successful management of severe malnutrition amongst children by workers at

Nutrition Care Centes and in family settings using standard protocols led to the wide scale replication of the approach by Anganwadi centres in different district of Rajasthan. The State Government also created an additional cadre of worker called 'Sahayogini' to support Anganwadi worker and promote better child caring practices at family level.

93. Kumar, S., R. Datta, S. Sinha, T. Kojima, S. Katoh and M. Mohan (2001). "**Carbon Stock, afforestation and acidic deposition: An analysis of inter-relation with reference to arid areas**." Water, Air, & Soil Pollution **130**(1): 1127-1132.

Recent advances in desert afforestation underline its viability and importance in combating global warming and acidification. In this paper, the inter-relation between afforestation, global warming and acid rain has been analyzed. Numerical simulations indicate that afforestation of deserts has distinct advantage as carbon sink and as an important factor for changing microclimate of the region rather than a source of energy. Acidic deposition may well be utilised as fertiliser in nutrient deficit soil of tropical arid areas. However, past trends and projections of acidic deposition in arid areas adjacent to **Thar Desert** indicate that early efforts are required to cap the opportunity. Delays may contribute towards more incidences of failures.

94. Lal, M. and B. Bhaskaran (1993). "**Impact of greenhouse warming on the climate of north-west India as inferred from a coupled atmosphere-ocean climate model**." Journal of Arid Environments **25**(1): 27-37.

One of the most significant consequences of climate change due to increasing concentrations of greenhouse gases in the atmosphere is a possible systematic increase in rainfall intensity over selected regions of the tropics. Despite the limited horizontal resolution, the current state-of-the-art coupled atmosphere-ocean general circulation models provide a qualitative description of the latitudinal and seasonal variations in rainfall type and intensity. In general, the model-simulated changes in the rainfall intensity under enhanced greenhouse conditions are found more statistically significant in terms of their uniformity on spatial and temporal scales. The air over the arid and semi-arid regions of India is relatively warmer during the daytime and hence has a larger water holding capacity. If a pronounced greenhouse warming were to occur over this region, the associated enhanced convective activity should lead to more extreme rainfall events. This could have strong implications for the hydrology and water resource of the region. Recently, a set of three time-dependent greenhouse warming simulations (IPCC's

scenarios A and D and a sudden increase of CO_2) and a reference control experiement have been performed with the Hamburg global coupled atmosphere-ocean general circulation model. The model has demonstrated substantial skill in simulating the present-day climate and its inter-annual variability over the monsoon region. Using the output of the Hamburg climate model, authors have examined the possible changes in the key climatological variables over the north-west margins of Indian sub-continent over the next 100 years. The results indicate that the warming is likely to be most pronounced over the north-west margins of India (**Thar Desert**) by the end of next century. However, inspite of the projected temperature rise and associated enhancement in evaporation rate, the non-availability of moisture could prohibit the deep convective activity in the region leading to more extensive deserts.

95. Laxmi, V., J. Parikh, S. Karmakar and P. Dabrase (2003). "**Household energy, women's hardship and health impacts in rural Rajasthan, India: need for sustainable energy solutions**." Energy for Sustainable Development **7**(1): 50-68.

The use of unprocessed bio-fuels for cooking is interlinked with many other factors such as socio-economic conditions, availability of alternative fuels, cooking practices, health impacts, gender equality, and housing characteristics. To examine these factors and their linkages, authors collected data through a large and comprehensive survey covering perhaps the largest sample of 58,768 individuals in 10,265 rural households from three states in northern India, viz., Uttar Pradesh, **Rajasthan** and Himachal Pradesh. Authors included socio-economic variables, smoking habits, fuels used, characteristics of the kitchen, cooking practices, 19 types of health symptoms, etc. In this paper, authors report on analysis of the data collected only from the rural areas of **Rajasthan**, covering 6,403 females and 5,552 males from 1,989 households in 13 villages. The results reveal that women undergo a lot of drudgery due to the use of bio-fuels. They walk approximately 2.5 km to collect fuel-wood. About 50 hours per month per household are expended in fuel-wood collection and transportation. The use of kerosene for cooking is negligible in the area, because of unavailability more than non-affordability. The people in the rural areas of **Rajasthan** are willing to pay for kerosene, the next fuel on the energy ladder above bio-fuels. It is estimated that even at a price of Rs. 13 per litre, which is higher than the market price, about 34 % of households are willing to buy additional quantities of kerosene for cooking. Therefore there is a need to meet this unmet demand by addressing market failures. The health impacts of the use of bio-fuels are quite high for adult women. The linkages between many socio-economic variables and respiratory

symptoms in adult women show that health impacts can be reduced by increasing female literacy, reducing the use of bio-fuels, and changing the housing design by, for example, introducing ventilation or separating the kitchen from the living area. The losses incurred because of cooking fuels, including work days spent, expenditure on illness and lost working days due to illness are Rs. 29 billion per year in the rural areas of **Rajasthan**. By minimizing these losses even by some fraction, one can give a boost to the rural economy and improve women's welfare. For this we need coordinated, consistent and focused cooperation of all the stakeholders at the grassroots, policy-making and implementation levels. Action-oriented programmes should include a treatment strategy at public health centres to help suffering women.

96. Machiwal, D., M. K. Jha, P. K. Singh, S. C. Mahnot, A. Gupta. (2004). "**Planning and design of cost-effective water harvesting structures for efficient utilization of scarce water resources in semi-arid regions of Rajasthan, India**." Water Resources Management **18**(3): 219-235.

Water-harvesting structures have the potential to increase the productivity of arable lands by enhancing crop yields and by reducing the risk of crop failure in arid and semi-arid regions, where water shortages are common because of scanty rainfall and its uneven distribution. In semi-arid regions of **Rajasthan**, India, existing practice of harvesting rainwater is through anicut and earthen embankments. In the present paper, the detailed design of some low-cost water-harvesting structures using locally available materials and adaptable to the socio-economic conditions of the beneficiaries is discussed. Two types of cost-effective water-harvesting structures, which include dry stone masonry and upstream-wall cement masonry of heights 1, 2, and 2.5 m for catchments of less than 10, 10 to 20, and 20 to 30 ha, respectively are proposed and designed. The analysis of costs involved in constructing dry stone masonry and upstream-wall cement masonry water-harvesting structures, emergency spillway, anicuts and earthen embankments revealed that the earthen embankments have the least cost of construction whereas the anicuts have the highest construction costs for all the selected heights. However, based on the past experiences, earthen embankments are not suitable for the semi-arid regions of **Rajasthan**. The economic evaluation of the proposed structures indicated that the dry stone masonry structures are very cost-effective for the region with a benefit-cost ratio of 3.5:1. Although the economic indicators ranked the upstream-wall cement masonry structures lower than the dry stone masonry structures, the former has greater stability and strength compared to the latter.

97. Madella, M. and Fuller, D.Q. (2006). "**Palaeoecology and the Harappan civilisation of South Asia: A reconsideration**." Quaternary Science Reviews **25**(11-12): 1283-1301.

Climatic change has often been cited as a determining factor in cultural Changes in the context of the Harappan Civilisation of northwestern South Asia, 2500-1900 BC. While these claims have been critiqued by archaeologists they continue to be accepted by non-archaeologists, including Quaternary scientists. The purpose of this paper is to assess the available evidence and published arguments and to provide a constructive working synthesis of evidence for the palaeoenvironniental setting of northwestern South Asia for the mid- to late Holocene, especially ca 4000-1000cal BC, and its possible connection to important Cultural changes. Authors conclude that Harappan urbanism emerged on the face of a prolonged trend towards declining rainfall. No climatic event call be blamed for a precipitous end of this civilisation, although strategic local shifts in agriculture that may have begun ill response to prolonged droughts at ca 2200 BC may have contributed to the de-urbanisation process and the restructuring of communities over the following 200-300yr.

98. Majra, J. P. and A. Gur (2009). **"Climate change and health: Why should India be concerned**." Indian Journal of Occupational and Environmental Medicine **13**(1): 11-16.

Overwhelming evidence shows that climate change presents growing threats to public health security - from extreme weather-related disasters to wider spread of such vector-borne diseases as malaria and dengue. The impacts of climate on human health will not be evenly distributed around the world. The Third Assessment Report (Intergovernmental Panel on Climate Change-2001) concluded that vulnerability to climate change is a function of exposure, sensitivity, and adaptive capacity. Developing country populations, particularly in small island states, arid and high mountain zones, and in densely populated coastal areas are considered to be particularly vulnerable. India is a large developing country, with the Great Himalayas, the world's third largest ice mass in the north, 7500 km long, and densely populated coast line in the south. Nearly 700 million of her over one billion population living in rural areas directly depends on climate-sensitive sectors (agriculture, forests, and fisheries) and natural resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods. Heat wave, floods (land and coastal), and draughts occur commonly. Malaria, malnutrition, and diarrhea are major public health problems. Any further increase, as projected in weather-related disasters and related health effects, may cripple the already inadequate

public health infrastructure in the country. Hence, there is an urgent need to respond to the situation. Response options to protect health from effects of climate change include mitigation as well as adaptation. Both can complement each other and together can significantly reduce the risks of climate change.

99. Mall, R. K., A. Gupta, R. Singh, R. S. Singh and L. S. Rathore (2006). "**Water resources and climate change: An Indian perspective**." Current Science **90**(12): 1610-1626.

In recent times, several studies around the globe show that climatic change is likely to impact significantly upon freshwater resources availability. In India, demand for water has already increased manifold over the years due to urbanization, agriculture expansion, increasing population, rapid industrialization and economic development. At present, changes in cropping pattern and land-use pattern, over-exploitation of water storage and changes in irrigation and drainage are modifying the hydrological cycle in many climate regions and river basins of India. An assessment of the availability of water resources in the context of future national requirements and expected impacts of climate change and its variability is critical for relevant national and regional long-term development strategies and sustainable development. This article examines the potential for sustainable development of surface water and groundwater resources within the constraints imposed by climate change and future research needs in India. In 124 years, probability of occurrence of drought was found maximum in west **Rajasthan** (25%), Saurashtra and Kutch (23%), followed by Jammu and Kashmir (21%), and Gujarat (21%).

100. Mall, R., R. Singh, A. Gupta, G. Srinivasan and L. Rathore (2006). "**Impact of climate change on Indian agriculture: A review**." Climatic Change **78**(2): 445-478.

During the recent decade, with the growing recognition of the possibility of climate change and clear evidence of observed changes in climate during 20th century, an increasing emphasis on food security and its regional impacts has come to forefront of the scientific community. In recent times, the crop simulation models have been used extensively to study the impact of climate change on agricultural production and food security. The output provided by the simulation models can be used to make appropriate crop management decisions and to provide farmers and others with alternative options for their farming system. It is expected that in the coming decades with the increased use of computers, the use of simulation models by farmers and professionals as well as policy and decision makers will increase. In India, substantial work has been

done in last decade aimed at understanding the nature and magnitude of change in yield of different crops due to projected climate change. This paper presents an overview of the state of the knowledge of possible effect of the climate variability and change on food grain production in India.

101. Malone, E. L. and A. Brenkert (2008). **"Uncertainty in resilience to climate change in India and Indian states**." Climatic Change **91**(3): 451-476.

This study builds on an earlier analysis of resilience of India and Indian states to climate change. The previous study (Brenkert and Malone, Clim Change 72:57–102, 2005) assessed current resilience; this research uses the Vulnerability–Resilience Indicators Model (VRIM) to project resilience to 2095 and to perform an uncertainty analysis on the deterministic results. Projections utilized two SRES-based scenarios, one with fast-and-high growth, one with delayed growth. The scenarios differ most significantly in the timing of the uncertainty in economic prosperity (represented by GDP per capita) as a major factor in explaining the uncertainty in the resilience index. In the fast-and-high growth scenario the states differ most markedly regarding the role of ecosystem sensitivity, land use and water availability. The uncertainty analysis shows, for example, that resilience in the Punjab might be enhanced, especially in the delayed growth scenario, if early attention is paid to the impact of ecosystems sensitivity on environmental well-being of the state. By the same token, later in the century land-use pressures might be avoided if land is managed through intensification rather than extensification of agricultural land. Thus, this methodology illustrates how a policy maker can be informed about where to focus attention on specific issues, by understanding the potential changes at a specific location and time—and, thus, what might yield desired outcomes. Model results can point to further analyses of the potential for resilience-building. Study finds six states to be more vulnerable than India as a whole, while the majority of states are more vulnerable than the global average.

102. Maurya, I. B., K. Arvindakshan, S. K. Sharma and R. Jalwania (2007). **"Status of indigenous vegetables in southern part of Rajasthan."** Acta Horticulturae **752**: 193-196.

Southern part of **Rajasthan** is predominantly a tribal dominated area having harsh climate, hence, only indigenous vegetables (IVs) which are hardy, drought resistant and have short duration grow well. Some of them namely kachari (*Cucumis melo* var. *agrestis*), snap melon (*Cucumis melo* var. *momordica* Duthie and Fuller), spine gourd (*Momordica dioica* Roxb. ex Wild.), bitter melon (*M*

balsamina L.) and hill colocynth [*Cucumis hardwickii* (Royle) Gabaev, grow naturally during rainy season and generate good source of income for the tribals. These vegetables possess very good nutritive and medicinal value with resistance to biotic and abiotic stresses but till now no systematic efforts have been made to improve the existing land races of these vegetables.

103. Mayewski, P. A., E. E. Rohling, J. C. Stager, W. Karlén, K. A. Maasch, L. D. Meeker, E. A. Meyerson, F. Gasse, S. van Kreveld, K. Holmgren, J. Lee-Thorp, G. Rosqvist, F. Rack, M. Staubwasser, R. R. Schneider, E. J. Steig. (2004). "**Holocene climate variability**." Quaternary Research **62**(3): 243-255.

The climate of the Holocene (11,500 cal yr B.P. to the present) has sustained the growth and development of modern society. Although the dramatic climate disruptions of the last glacial period have received considerable attention, relatively little has been directed toward climate variability in the Holocene. Examination of ~50 globally distributed paleoclimate records reveals as many as six periods of significant rapid climate change during the time periods 9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600–150 cal yr B.P. Most of the climate change events in these globally distributed records are characterized by polar cooling, tropical aridity, and major atmospheric circulation changes, although in the most recent interval (600–150 cal yr B.P.), polar cooling was accompanied by increased moisture in some parts of the tropics. Several intervals coincide with major disruptions of civilization, illustrating the human significance of Holocene climate variability.

104. Meher-Homji, V. M. (1973). **"Is the Sind-Rajasthan desert the result of a recent climatic change?"** Geoforum **4**(3): 47-57.

The author reviews the problem whether the Sind-**Rajasthan** desert of the Indo-Pakistan sub-continent is of recent origin and which factors are responsible for its creation: climatic change, shifting of rivers, floods, or yet social causes such as wars and man's abuse of his environment resulting in ecological imbalance.

105. Messerli, B., M. Grosjean, T. Hofer, L. Nunez, C. Pfister. (2000). **"From nature-dominated to human-dominated environmental changes."** Quaternary Science Reviews **19**(1-5): 459-479.

To what extent is it realistic and useful to view human history as a sequence of changes from highly vulnerable societies of hunters and gatherers through periods with less vulnerable, well buffered and highly productive agrarian-urban societies to a world with regions of extreme overpopulation and overuse of life support systems, so that vulnerability to climatic-environmental changes and extreme events is

again increasing? This question cannot be fully answered in our present state of knowledge, but at least we can try to illustrate, with three case studies from different continents, time periods and ecosystems, some fundamental changes in the relationship between natural processes and human activities that occur, as we pass from a nature-dominated to a human dominated environment.

1. Early-mid Holocene: Nature dominated environment — human adaptation, mitigation, and migration. In the central Andes, the Holocene climate changed from humid (10,800–8000 BP) to extreme arid (8000–3600 BP) conditions. Over the same period, prehistoric hunting communities adopted a more sedentary pattern of resource use by settling close to the few perennial water bodies, where they began the process of domesticating camelids around 5000 BP and irrigation from about 3100 BP.

2. Historical period: An agrarian society in transition from an "enduring" to an innovative human response. Detailed documentary evidence from Western Europe may be used to reconstruct quite precisely the impacts of climatic variations on agrarian societies. The period considered spans a major transition from an apparently passive response to the vagaries of the environment during the 16th century to an active and innovative attitude from the onset of the agrarian revolution in the late 18th century through to the present day. The associated changes in technology and in agricultural practices helped to create a society better able to survive the impact of climatic extremes.

3. The present day: A human dominated environment with increasing vulnerability of societies and economies to extreme events and natural variability. The third example, dealing with the history and impact of floods in Bangladesh, shows the increasing vulnerability of an over-exploited and human-dominated ecosystem. Measurements exist for a short time only (decades), historical data allow a prolongation of the record into the last century, and paleo-research provides the long-term record of processes operating over millennia. The long-term paleo-perspective is essential for a better understanding of future potential impacts on an increasingly human-dominated environment. Understanding today's global change processes calls for several new perspectives and synergisms:

• the integration of biophysically oriented climate change research with research about the increasingly dominant processes of human forcing,

• a focus on overexploited or limited natural resources and on vulnerable and critical regions,

• fuller use of our understanding of variability on a range of different timescales: "The present without a past has no future".

106. Mruthyunjaya, S. P. Malhotra and A. K. Sen (1983). **"Technological possibilities for agricultural growth and stability in western Rajasthan: an assessment (India)."** Annals of Arid Zone **22**(2): 121-133.

Agriculture in W **Rajasthan** is not only backward, but also highly unstable. Money spent by government on famine relief over years has neither strengthened the production base of the economy nor enabled it to mitigate the rigours imposed by recurring droughts and famines. The problems and prospects of the application of arid zone technologies as a permanent solution to the arid zone problems is assessed. More food, fodder, and fuel can be produced. Adequate employment is also possible. However, it shows that application of technologies needs pooling of state, national, and even international resources.

107. Mukhopadhyay, D. (2008). "**Indigenous knowledge and sustainable natural resource management in the Indian desert**." In, C. Lee and T. Schaaf (eds.). The Future of Drylands. Netherlands, Springer: pp. 161-170.

Indian local communities in the desert have often shown that they are good managers of their natural resource base through their traditional knowledge and wisdom. Efficient community strategies have exemplified their intelligent and sustainable use of land, water and soil without causing damage to the resilience and functioning of the surrounding ecosystem. The Bishnoi tribe of the western Indian state of **Rajasthan** has over the centuries combined a unique blend of ecological sense and religious sensibility. The **Thar Desert** in India is full of ironies — one of them being the Bishnoi community of **Rajasthan**. Here, peace is maintained with aggression, and robust health rubs shoulders with regular famine. Living amidst the barren wastelands interspersed with Khejri and Babool trees, the Bishnois are a proud race. Johra Ram, head of the Bishnoi community, says "Any change in the world has to begin within the society. All this talk about nature and wildlife protection would be more effective if each individual was to believe in the Earth as a living, breathing entity and fight for its survival the way we do." There is a story of Amrita Devi a Bishnoi woman who, along with more than 366 other Bishnois, died saving trees. The Bishnois are an example of people living in harmony with nature where they maintaingroves, locally known as orans, where animals graze and birds feed. Orans serve as important rechargers of rainwater in the desert aquifers, where every single drop of water is precious. It is estimated that orans account for about 9%

of the desert area. Here, the tree species, *Prosopis cineraria* or Khejari, is worshipped for its immense ecological value.

108. Neff, U., S. J. Burns, A. Mangini, M. Mudelsee, D. Fleitmann, and A. Matter. 2001. "**Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago**." Nature **411**: 290-293.

Variations in the amount of solar radiation reaching the Earth are thought to influence climate, but the extent of this influence on timescales of millennia to decades is unclear. This research suggests that one of the primary controls on centennial- to decadal-scale changes in tropical rainfall and monsoon intensity during this time are variations in solar radiation.

109. Negi, B. S., S. Sadasivan, K. S. V. Nambi and B. M. Pande (1996). **"Characterization of atmospheric dust at Gurushikar, Mt. Abu, Rajasthan."** Environmental Monitoring and Assessment **40**(3): 253-259.

The nature of atmospheric aerosols at Gurushikar, Mt. Abu, **Rajasthan** where a gamma ray telescope is to be installed, was investigated. Air particulate samples collected on filters were used to estimate the total suspended particulate matter (TSPM) and its elemental composition. The TSPM varied from 31 to 103 $\mu g/m^3$ during January to March 1994. The heighest loads were observed during the months of May and June (80-100 $\mu g/m^3$) and lowest during October (20-60 $\mu g/m^3$. The dust was also examined for size, shape and nature of the mineral matter. The particle sizes varied from 100 μm to 5 μm. The course particles (> 50 μm) are irregular shaped quartz grains. Some of the medium size (= 50 μm) particles were spherical and were highly conducting. These particles were rich in iron content. Correlation coefficients among various elements in the dust showed that it is made up of mainly two components - wind blown ground dust and particulate arising out of wood and coal burning.

110. Noss, R. F. (2001). **"Beyond Kyoto: forest management in a time of rapid climate change**." Conservation Biology **15**(3): 578-590.

Policies to reduce global warming by offering credits for carbon sequestration have neglected the effects of forest management on biodiversity. Author reviews properties of forest ecosystems and management options for enhancing the resistance and resilience of forests to climate change. Although forests, as a class, have proved resilient to past changes in climate, today's fragmented and degraded forests are more vulnerable. Adaptation of

species to climate change can occur through phenotypic plasticity, evolution, or migration to suitable sites, with the latter probably the most common response in the past. Among the land use and management practices likely to maintain forest biodiversity and ecological functions during climate change are: (1) representing forest types across environmental gradients in reserves; (2) protecting climatic refugia at multiple scales; (3) protecting primary forests; (4) avoiding fragmentation and providing connectivity, especially parallel to climatic gradients; (5)providing buffer zones for adjustment of reserve boundaries; (6) practicing low-intensity forestry and preventing conversion of natural forests to plantations; (7) maintaining natural fire regimes; (8) maintaining diverse gene pools; and (9) identifying and protecting functional groups and keystone species. Good forest management in a time of rapidly changing climate differs little from good forest management under more static conditions, but there is increased emphasis on protecting climatic refugia and providing connectivity.

111. O'Brien, K., R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, J. West. (2004). "**Mapping vulnerability to multiple stressors: climate change and globalization in India**." Global Environmental Change **14**(4): 303-313.

There is growing recognition in the human dimensions research community that climate change impact studies must take into account the effects of other ongoing global changes. Using the example of Indian agriculture, this paper presents a methodology for investigating regional vulnerability to climate change in combination with other global stressors. This method, which relies on both vulnerability mapping and local-level case studies, may be used to assess differential vulnerability for any particular sector within a nation or region, and it can serve as a basis for targeting policy interventions. Among India's population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector. The areas with high to very high climate sensitivity for agriculture are located in the semiarid regions of the country, including major parts of the states of **Rajasthan**, Gujarat, Punjab, Haryana, Madhya Pradesh, and Uttar Pradesh.

Based on the biophysical, social, and technological indicators adaptive capacity in 1991 across India's 466 districts has been identified. There is a higher degrees of adaptive capacity in districts located along the Indo-Gangetic Plains (except Bihar) and lower adaptive capacity in the interior portions of the country, particularly in the states of Bihar,

Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka.

The globalization vulnerability profile was constructed by combining for each district the values of the adaptive capacity and import sensitivity indices. High vulnerability is visible in most of **Rajasthan** and Karnataka, as well as in substantial portions of Bihar, Madhya Pradesh, Maharashtra, Gujarat, and Assam. Notable areas of low vulnerability occur along the Indo-Gangetic plains, a highly productive region that is commonly referred to as the breadbasket of India.

Vulnerability to climate change and globalization: The most vulnerable concentrated in **Rajasthan**, Gujarat, Madhya Pradesh, as well as in southern Bihar and western Maharashtra. These may be interpreted as areas of "double exposure," where globalization and climate change are likely to pose simultaneous challenges to the agricultural sector.

Why are these "double exposed" districts, such as Jhalawar in **Rajasthan**, a concern? They are likely to be areas where farmers are adapting to a variable and changing climate under conditions of economic stress. Reacting to two processes of change simultaneously will, of course, present challenges throughout India, but these districts are likely to feel disproportionately more stress, particularly if there is a mismatch between climate-compatible crops and market-driven demand for those crops. It is in these areas of double exposure where policy changes and other interventions may be most needed in order to help farmers to negotiate changing contexts for agricultural production.

112. O'Neill, B. C., K. Riahi and I. Keppo (2010). "**Mitigation implications of midcentury targets that preserve long-term climate policy options**." Proceedings of the National Academy of Sciences **107**(3): 1011-1016.

Midcentury targets have been proposed as a guide to climate change policy that can link long-term goals to shorter-term actions. However no explicit mitigation analyses have been carried out of the relationship between midcentury conditions and longer-term outcomes. Here authors use an integrated assessment modeling framework with a detailed representation of the energy sector to examine the dependence of climate change outcomes in 2100 on emissions levels, atmospheric concentrations, and technology characteristics in 2050. Authors find that midcentury conditions are crucial determinants of longer-term climate outcomes, and identify feasibility thresholds describing conditions that must be met by

midcentury to keep particular long-term options open. For example, to preserve the technical feasibility of a 50% likelihood of keeping global average temperature at < 2 °C above preindustrial in 2100, global emissions must be reduced by about 20% below 2000 levels by 2050. Results are sensitive to several assumptions, including the nature of future socio-economic development. In a scenario with high demand for energy and land, being below 2 °C with 50% likelihood requires a 50% reduction in emissions below 2000 levels by 2050, which is only barely feasible with known technologies in that scenario. Results suggest that a greater focus on midcentury targets could facilitate the development of policies that preserve potentially desirable long-term options.

113. O'Reilly, K. (2010). **"Combining sanitation and women's participation in water supply: An example from Rajasthan."** Development in Practice **20**(1): 45-56.

Water supply and sanitation provision are key elements in progress towards the Millennium Development Goals (MDGs). Women's participation is considered integral to the sustainability of the projects created to meet these two MDGs. Bringing feminist and geographic critiques to bear on gendered approaches to improving sanitation coverage, the research reported on in this article indicates that latrine building and women's participation may be contradictory goals for sanitation projects, despite the fact that women are the target group for latrine-building interventions. The findings of the analysis suggest that attention must be given to latrine building as both a technical undertaking and a gendered political intervention.

114. Ojasvi, P. R., R. K. Goyal and J. P. Gupta (1999). **"The micro-catchment water harvesting technique for the plantation of jujube (*Zizyphus mauritiana*) in an agroforestry system under arid conditions."** Agricultural Water Management **41**(3): 139-147.

The shallow conical micro-catchments of 1.0 m radius constructed around the plant saplings were used to establish jujube (*Zizyphus mauritiana*) in arid conditions. The catchment surface was also lined with different waste materials like polythene bags, newspaper, stone and marble pieces. Results of the 2-year study showed significant treatment effects on the growth of jujube plants. Catchment lining also helped in maintaining the higher soil moisture status over the control (unlined) catchment. The stone and marble piece linings significantly increased the plant height by 40–48% over the control, the effect of other treatments are statistically similar. It was also found that the plants with micro-catchment have better chances of establishment in rainfed conditions as compared to conventional plantation technique.

115. Overpeck, J., D Anderson, S. Trumbore, W. Prell. (1996). "**The southwest Indian Monsoon over the last 18,000 years**." Climate Dynamics **12**(3): 213 – 225.

Authors present new, well-dated, multi-proxy records of past monsoon variation from three separate Arabian Sea sediment cores that span the last glacial maximum to late-Holocene. To a large extent, these records confirm earlier published suggestions that the monsoon strengthened in a series of abrupt events over the last deglaciation. However, this data provide a somewhat refined picture of when these events took place, and suggest the primacy of two abrupt increases in monsoon intensity, one between 13 and 12.5 ka, and the other between 10 and 9.5 ka. This analysis suggests that the monsoon responded more linearly to insolation forcing after the disappearance of glacial boundary conditions, decreasing gradually after about 6 ka. This research also supports the possibility that significant century-scale decreases in monsoon intensity took place during the early to mid-Holocene period of enhanced monsoon strength.

116. Paavola, J. & W. Neil Adger. (2006). "**Fair adaptation to climate change**." Ecological Economics **56**(4): 594-609.

Authors propose the adoption of four principles for fair adaptation in the climate change regime. These include avoiding dangerous climate change, forward-looking responsibility, putting the most vulnerable first and equal participation of all. Authors argue that a safe maximum standard of 400–500 ppm of CO_2 concentrations in the atmosphere and a carbon tax of $20–50 per carbon equivalent ton could provide the initial instruments for operationalising the principles.

117. Pachauri, R. K. (2004). "**Climate change and its implications for development: the role of IPCC assessments**." IDS Bulletin **35**(3): 11-14.

The Intergovernmental Panel on Climate Change (IPCC) Reports show that climate change is likely to have significant developmental consequences for all, but developing countries and the poor persons within all countries will be disproportionately affected by impacts on agriculture, health and water. As the largest source of employment in most developing countries, impacts on agriculture and on food security are especially critical. Altered precipitation rates will also result in more frequent droughts and floods in large parts of Asia and could impact adversely on the achievements of the Millennium Development Goals (MDGs) on water and sanitation, which are linked to other MDGs. Vulnerability of agriculture and

options for adaptation have only recently been studied in India in detail. These indicate serious problems for India, as there are limited opportunities for changes in crops, compounded by other factors such as unfavourable global trading regimes.

118. Palm, M., M. Ostwald, G. Berndes and N. H. Ravindranath (2009). "**Application of Clean Development Mechanism to forest plantation projects and rural development in India.**" Applied Geography **29**(1): 2-11.

This paper analyses the prospects for establishing afforestation and reforestation Clean Development Mechanism (CDM) projects in India. Building on multi-disciplinary fieldwork, the aim is to: (i) establish what type of plantations and forests that would best suit a forest-based project activity, considering global climate benefits and local sustainable development objectives; (ii) identify the parameters that are important for ensuring sustainable development at the local level and (iii) develop a transparent ranking tool for the assessment of possible forest-based project activities. Using equal weights for the ranking parameters and a 30-year time horizon, the ranking shows that plantations managed with the shortest rotation period (5 years) would be most suitable for forest-based project activities. However, the performance of individual forest-based project activities will depend on local conditions, which need to be reflected in the weighting procedure. Sensitivity analysis shows that when weights are varied, other forest types can become the preferred option. Based on a combination of the sensitivity analysis and results from the fieldwork, it can be concluded that successful implementation of forest-based project activities will require local participation and are likely to involve multiple forest products and environmental services demanded by the local community.

119. Panda, A. (2009). "**Assessing vulnerability to climate change in India**." Economic & Political Weekly **44**(16): 105-107.

The impact of climate change on the lives and livelihoods of people in India is now widely recognised. Yet, there is neither a consensus on the definition of vulnerability to climate change nor a full, regionally-nuanced mapping of the variable impact of such a change. It is only when a better understanding of what constitutes vulnerability to climate change and what its region-specific impact would be is available that proper adaptation strategies can be worked out. The states of Bihar, **Rajasthan**, Gujarat, Punjab, Haryana, Madhya Pradesh, Maharatra, Andhra Pradesh and Karnataka have the lowest adaptive capacity. The areas of greatest climate sensitivity are **Rajasthan**, Madhya Pradesh and Uttar Pradesh.

120. Pandey, D. N. (2001). "**A bountiful harvest of rainwater**." Science **293**(5536): 1763.

Over thousands of years, societies have developed a diversity of local water harvesting and management regimes that continue to survive in South Asia, Africa, and other parts of the world. Such systems are often integrated with agroforestry and local forest management practices. Recent studies have proposed several market mechanisms for sustainable water management, including taxing users to pay commensurate costs of supply and distribution and costs of integrated watershed management, and charging polluters for effluent treatment. Although such measures are indeed essential, Author argues here that they are insufficient: They should be complemented with policy innovations to promote rainwater harvesting. Revival of local practices of rainwater harvesting could provide substantial amounts of water. For example, a hectare of land in Barmer, one of India's driest places, with 100 millimeters of rainfall annually, could yield 1 million liters of water per year from harvesting rainwater. Even with simple technology such as ponds and earthen embankments called tanks, at least half a million liters a year can be harvested from rain falling over 1 hectare of land, as is being done in the **Thar Desert**, making it the most densely populated desert in the world. Indeed, there are 1.5 million village tanks in use and sustaining everyday life in the 660,000 villages in India. Indeed, this is consistent with local knowledge distilled in an Indian proverb, "Capture rain where it rains." In the cities, rainwater could be harvested from building rooftops for residential use, and any surplus could be channeled through bore wells to replenish the groundwater, avoiding loss to runoff. However, if tanks and other rain harvesting technology are to be used to their full potential, policy innovations must include institutional changes so that such common-pool resources are effectively managed. Also, all forms of government subsidies need to be removed to allow market mechanisms, such as the ones Johnson et al. discuss, to run their course. Users would then find it prudent not only to make efficient use of priced water, but they would also have the incentive to collect the gift that Mother Nature has to offer in the form of rain.

121. Pandey, D. N. (2002). "**Carbon sequestration in agroforestry systems**." Climate Policy **2**(4): 367-377.

Management of trees in agroecosystems such as agroforestry, ethnoforests, and trees outside forests can mitigate green house gas (GHG) emissions under the Kyoto Protocol. Agroforestry systems are a better climate change mitigation option than oceanic, and other terrestrial options because of the secondary environmental benefits

such as helping to attain food security and secure land tenure in developing countries, increasing farm income, restoring and maintaining above-ground and below-ground biodiversity, corridors between protected forests, as CH_4 sinks, maintaining watershed hydrology, and soil conservation. Agroforestry also mitigates the demand for wood and reduces pressure on natural forests. Promoting woodcarving industry facilitates long-term locking-up of carbon in carved wood and new sequestration through intensified tree growing. By making use of local knowledge, equity, livelihood security, trade and industry, can be supported. There is need to support development of suitable policies, assisted by robust country-wide scientific studies aimed at better understanding the potential of agroforestry and ethnoforestry for climate change mitigation and human well-being.

122. Pandey, D. N. (2002). "**Global climate change and carbon management in multifunctional forests**." Current Science **83**(5): 593-602.

Fossil-fuel burning and deforestation have emerged as principal anthropogenic sources of rising atmospheric CO_2 and consequential global warming. Variability in temperature, precipitation, snow cover, sea level and extreme weather events provide collateral evidence of global climate change. Author reviews recent advances on causes and consequences of global climate change and its impact on nature and society. Author also examine options for climate change mitigation. Impact of climate change on ecology, economy and society -the three pillars of sustainability - is increasing. Emission reduction, although most useful, is also politically sensitive for economic reasons. Proposals of the geoengineering for iron fertilization of oceans or manipulation of solar flux using stratospheric scatters are yet not feasible for scientific and environmental reasons. Forests as carbon sinks, therefore, are required to play a multifunctional role that includes, but is not limited to, biodiversity conservation and maintenance of ecosystem functions; yield of goods and services to the society; enhancing the carbon storage in trees, woody vegetation and soils; and providing social and economic well-being of people. This paper explores strategies in that direction and concludes that the management of multifunctional forests over landscape continuum, employing tools of conservation biology and restoration ecology, shall be the vital option for climate change mitigation in future.

123. Pandey, D. N. (2004). "**Equity in climate change treaty**." Current Science **86**(2): 272-281.

The Kyoto Protocol of the United Nations Framework Convention on Climate Change seeks to achieve climate stability and sustainable development through global cooperation. Even with spectacular advances in climate science, projected economic and health benefits of greenhouse gas mitigation, and presence of all the key elements for an effective treaty in the Kyoto Protocol, climate change negotiations remain inconclusive. Arguably, this is so because a widespread concern on equity is yet to be resolved. Here author reexamines the equity in climate change treaty. Political leadership, scientific community and civil society in several nations have maintained that the democratic norms for climate governance are a prerequisite for crafting a successful climate change treaty. Principle of equal per capita emission entitlements is now emerging as the key option beyond current impasse. Although not required under the Kyoto Protocol, several developing nations are taking responsible action to mitigate climate change. Principle of equal per capita emission entitlements is a just solution to successfully implement climate treaty aimed at climate change mitigation, adaptation and sustainable development. Without a full and unequivocal commitment to equity and democratic governance by a cohesive humanity, any international climate change treaty will have only limited utility.

124. Pandey, D. N. (2006). **"Connectiong science to decision making for combating desertification in India**." Financing Agriculture **38**(5): 29-33.

Sustainable development that promotes ecological sustainability and human well-being is a practical necessity of our times. Ecological sustainability can not be achieved without reducing poverty and provisioning for the just and dignified improvements in livelihoods. Likewise, nor can sustainable human well-being be achieved without sustainable environmental management. Therefore, investing in creation, communication and linking knowledge to field and policy action is necessary for both poverty reduction and ecosystem sustainability. Linking knowledge to action is necessary to concurrently combat desertification and ensure livelihoods of people dwelling in dry tropics. Scientists and practitioners are required to be aware of the intricacies about what makes knowledge applicable and what it takes to produce the science that makes an impact on the ground.

125. Pandey, D. N. (2007). **"Multifunctional agroforestry systems in India."** Current Science **92**(4): 455-463.

Land-use options that increase resilience and reduce vulnerability of contemporary societies are fundamental to livelihood

improvement and adaptation to environmental change. Agroforestry as a traditional land-use adaptation may potentially support livelihood improvement through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change. Drawing on the representative literature, here, author critically reviews the contribution of agroforestry systems in India to: (i) biodiversity conservation; (ii) yield of goods and services to society; (iii) augmentation of the carbon storage in agroecosystems; (iv) enhancing the fertility of the soils, and (v) providing social and economic well-being to people. Agroforestry systems in India contribute variously to ecological, social and economic functions, but they are only complementary – and not as an alternative – to natural ecosystems. To promote well-being of the society, management of multifunctional agroforestry needs to be strengthened by innovations in domestication of useful species and crafting market regimes for the products derived from agroforestry and ethnoforestry systems. Future research is required to eliminate many of the uncertainties that remain, and also carefully test the main functions attributed to agroforestry against alternative land-use options in order to know unequivocally as to what extent agroforestry served these purposes.

126. Pandey, D. N., A. C. Chaubey, A. K. Gupta and H. Vardhan (2005). "**Mine spoil restoration: A strategy combining rainwater harvesting and adaptation to random recurrence of droughts in Rajasthan**." International Forestry Review **7**(3): 241-249.

Rajasthan presents evidence for the existence of one of the most advanced examples of ancient mining and accompanied deforestation to be found anywhere in the world. Mining continues to be an important economic activity contributing to 2% of the State Domestic Product and providing at least a 1.76 % share to the regular employment pool in **Rajasthan**. However, economic benefits of mineral extraction also accompany environmental, economic and social costs. Mine waste dumps and mined out areas viewed simply as the legacies of past may appear overwhelming environmental hazards presenting ugly picture of cultural landscape. However, mine wastes can be transformed into an opportunity for learning, adaptation and productivity enhancement for sustainable livelihoods through ecological restoration. Here authors propose a strategy for mine spoil restoration aimed at creating a multifunctional ecosystem in mine waste dumps. It is suggested that dredging and sediment removal from traditional tanks and ponds can potentially be used to prepare the substratum over the mine wastes for direct seeding. It will also create enhanced decentralized water storage capacity for wildlife and people. The strategy combines the concomitant revival of traditional water harvesting systems, ground water recharge, enhanced biomass

production and an adaptation to random recurrence of droughts in **Rajasthan**.

127. Pandey, D. N., A. K. Gupta, D. M. Anderson. (2003). "**Rainwater harvesting as an adaptation to climate change**." Current Science **85**(1): 46-59.

Extreme climate events such as aridity, drought, flood, cyclone and stormy rainfall are expected to leave an impact on human society. They are also expected to generate widespread response to adapt and mitigate the sufferings associated with these extremes. Societal and cultural responses to prolonged drought include population dislocation, cultural separation, habitation abandonment, and societal collapse. A typical response to local aridity is the human migration to safer and productive areas. However, climate and culture can interact in numerous ways. Authors hypothesize that people may resort to modify dwelling environments by adapting new strategies to optimize the utility of available water by harvesting rain rather than migrating to newer areas. Authors review recent palaeoclimatological evidence for climate change during the Holocene in India, and match those data with archaeological and historical records to test the climate change-rainwater harvest hypothesis. Periods of climate change and aridity and consequent adaptation responses for rainwater harvesting in **Rajasthan** are specifically highlighted. Article finds a correlation between heightened historical human efforts for construction of rainwater harvesting structures across regions in response to abrupt climate fluctuations, like aridity and drought. Historical societal adaptations to climate fluctuations may provide insights on potential responses of modern societies to future climate change that has a bearing on water resources, food production and management of natural systems.

128. Pandey, N. 2002. "**Gender economics of the Kyoto Protocol**." Conservation Ecology **6**(1): r14. [online] URL: http://www.consecol.org/vol6/iss1/resp14

Global climate change is threatening the social, economic, and ecological systems of our world. Cost effectiveness of the Kyoto Protocol presents a compelling argument for its implementation. Missing from the climate-change debate, however, is the differential impact of climate change on women, and how implementation of the Kyoto Protocol could specifically benefit economically disadvantaged women in developing countries. The argument favoring implementation of the Kyoto Protocol would be strengthened if it included a recognition of gender economics. Any fruitful discussion on the economics of climate change must consider: the additional work burden of women and female children; the differences,

according to gender, in access to resources and consumption patterns; and the comparative vulnerability of women to climate change. Men and women have differential knowledge of local resources and climate issues. Women can play a crucial role in climate-change mitigation through adaptive management of local resources, thereby saving ecosystems from catastrophic shifts. Women should be active and equal partners in the decision-making process on the Clean Development Mechanism, as well as in capacity building, technology transfer, vulnerability studies, and projects concerning climate-change mitigation and adaptation. Scientific and policy efforts on climate-change mitigation and sustainable development should, therefore, also pay attention to the profound influence that gender economics has in any collective attempt to build a sustainable society.

129. Pandey, N., C. Prakash and D. N. Pandey (2007). "**Linking knowledge to action for sustainable development in India"**. In, S. Mudrakartha (ed.), Empowering the Poor in the Era of Knowledge Economy. VIKSAT, Ahmedabad, pp. 4-10.

Sustainable development is driven by knowledge because progress of society towards sustainability is a knowledge-intensive enterprise. Investing in creation, communication and linking knowledge to field and policy action is therefore necessary for ecological, economic and social well-being. While India ranks very high in terms of number of research papers published annually, when it comes to linking that knowledge to action for bringing human development it ranks very poorly. The Human Development Index (HDI) for India is 0.611, which gives India a rank of 126th out of 177 countries. Drawing on the pioneering efforts on linking knowledge to action, here we argue that in order to reduce poverty and bring sustainable human development a concerted effort is required to design and implement strategies for connecting science to decision making across scales and sectors in India. This article presents a potential strategy for connecting science to decision-making. Good research is required to produce knowledge and a robust knowledge supply-chain is essential to link knowledge to policy and field action. Authors call upon the scientists to employ strategies for co-production of knowledge, and for people engaged in capacity building programs to employ co-synthesis of knowledge useful to solve the field problems. Practitioners and policy makers on their part are expected to link that knowledge to both field and policy to design and implement interventions for sustainable development.

130. Pandey, P. D. 2003. "**Child participation for conservation of species and ecosystems**." Conservation Ecology **7**(1): r2. [online] URL: http://www.consecol.org/vol7/iss1/resp2/

If we assume that children have an innate desire to be near plants and animals, then it would follow that innovative strategies for the conservation of species and ecosystems would benefit from child participation. Accordingly, it seems to me that conservationists worldwide are more likely to succeed in their noble efforts if they implement innovative programs that involve working with children. By doing so, they will also nurture the spirit of innovation in the conservationists of the future. For this reason, it is suggested that child participation in conservation should be seriously considered as a way of making the "kaleidoscope of change" more beautiful. Child participation in conservation can help children grow into environmentally friendly adults. Children have an inherent desire to run after butterflies, love beautiful birds and wild places, and want to make friends with elephants and tigers. Parents know all too well how easily a child can persuade them to spend money on an aquarium teeming with a variety of fish. Dogs, cats, and parrots are all-time favorites. Children enjoy dragonfly pond restoration programs, are fascinated by large animals in zoos, and prefer to play in yards full of flowers and butterflies. Children also learn by being in the company of nature. However, the amount of knowledge a child possesses depends entirely on the way in which he or she is brought up. For example, the knowledge bases of children living in Indian villages and those living in London are obviously going to be quite different. Even in India, the average 10-year-old living in a village knows the local names of hundreds of birds, plants, insects, scorpions, and other creatures, whereas children raised in Delhi find it hard to name even a few. Clearly, child participation for the conservation of beautiful species and wonderful ecosystems is a must. However, we should not forget that all species in their natural habitats are beautiful and all protected ecosystems are wonderful.

131. Pant, G. B. and L. S. Hingane (1988). "**Climatic changes in and around the Rajasthan desert during the 20th century**." Journal of Climatology **8**(4): 391-401.

Rainfall and temperature data during the period 1901-1982 are studied for the northwest Indian region consisting of the meteorological subdivisions of Punjab, Haryana, west **Rajasthan**, east Rajasthan and west Madhya Pradesh. The results indicate a decreasing trend in the mean annual surface air temperature, which is mainly contributed by the south-west monsoon season (June through September), The mean annual and south-west monsoon season

rainfall series over most parts of the region indicate a conspicuous increasing trend. The increasing trend is significantly marked for the subdivisions constituting the peripheral areas of the **Rajasthan** desert. These trends in rainfall and temperature are examined in relation to the changing land use pattern of the region due to extensive irrigation. Earlier finding of Winstanley (1973) reporting the decreasing trend in rainfall is found to be unacceptable due to the unrealistic assumptions of his study.

132. Panwar, N. L. and N. S. Rathore (2009). **"Potential of surplus biomass gasifier based power generation: A case study of an Indian state Rajasthan."** Mitigation and Adaptation Strategies for Global Change **14**(8): 711-720.

Energy from surplus biomass can support an essential contribution to a sustainable energy generation. This paper deals with a case study of surplus biomass available in the Indian state **Rajasthan**. About 1275 MW electrical power is possible to generate through biomass gasifier based power generation plant through surplus biomass available in **Rajasthan**. About 1656 tonnes of CO_2 can be saved annually by installation of 1 MW biomass gasifier based power plant. The techno economic parameter like net present worth, cost benefit ratio and pay back period are also carried out for this route of power generation and these are about 1. 18 million US$, 1. 42 and 8 years and 2 months respectively.

133. Panwar, N., A. Kurchania and N. Rathore (2009). **"Mitigation of greenhouse gases by adoption of improved biomass cookstoves."** Mitigation and Adaptation Strategies for Global Change **14**(6): 569-578.

Greenhouse gases especially CO_2 can be reduced with the help of improved biomass cookstoves. This paper deals with the design and development of biomass stoves (single pot and double pot) with better efficiency for meeting household cooking energy requirement. Thermal performance, flue gas emission of carbon monoxide (CO) and carbon dioxide (CO_2) have been investigated. It was seen from the result that the flue gas emission is within permissible limit as recommended by World Health Organization. The design of improved biomass stove sent to Palampur center situated in Himalaya in hilly terrain of India, where the acceptability of double pot stoves (85%) is quite high compared to single pot stoves (30%). Thermal efficiencies of both single and double pot stove were recorded about 21% and 25% respectively. An improved biomass cookstove can save about 161 kg of CO_2 annually. Improved cookstoves was found eco-friendly in nature and suitable for the cooking requirement of hilly areas.

134. Pareek, O. P., B. B. Vashishtha, D. K. Samadia. (1999). **"Genetic diversity in drought hardy cucurbits from hot arid zone of India."** IPGRI Newsletter for Asia, the Pacific and Oceania(No. 28): 22-23.

A total of 842 open-pollinated semi-cultivated landraces of mateera (*Citrullus lanatus*), kachari (*Cucumis callosus*), snap melon (*Cucumis melo*) were collected in the north-western parts of **Rajasthan** in 1995 and evaluated. Some accessions with economic and nutritional potential for cultivation in the arid regions of India as an adaptation were identified.

135. Parthasarathy, B., N. A. Sontakke, A. A. Monot and D. R. Kothawale (1987). **"Droughts/floods in the summer monsoon season over different meteorological subdivisions of India for the period 1871-1984."** International Journal of Climatology **7**(1): 57-70.

Abnormalities in the performance of the Indian summer monsoon (June to September) rainfall, which provides 75-90 per cent of annual rainfall, have been studied during the period 1871 to 1984 over different meteorological subdivisions. Long homogeneous monsoon rainfall series of 29 subdivisions, prepared on the basis of a constant 306 rain gauges, have been tabulated for the users in view of their great importance. The criterion adopted in identification of drought/flood over a subdivision is the percentage of rainfall departures from normal, as officially used in the India Meteorological Department. The worst drought years were 1877, 1899, 1911, 1918, 1920, 1951, 1965 and 1972 and the worst flood years were 1892, 1933, 1961 and 1983 when many subdivisions reported extremely low and excess rainfall, respectively. The probabilities of occurrence of droughts/floods are high in Haryana, Punjab, west **Rajasthan**, Gujarat and Saurashtra and Kutch subdivisions. The area of the country affected by drought conditions was at a maximum during the decade 1911-1920 and at a minimum during the decade 1881-1890. The decades 1971-1980 and 1921-1930 were characterized by maximum and minimum areas, respectively, under flood conditions. The percentage area of India which suffered from drought and flood was low during the continuous three decades 1921-1930, 1931-1940 and 1941-1950.

136. Pathak, H., N. Jain, A. Bhatia, S. Mohanty and N. Gupta (2009). **"Global warming mitigation potential of biogas plants in India."** Environmental Monitoring and Assessment **157**(1): 407-418.

Biogas technology, besides supplying energy and manure, provides an excellent opportunity for mitigation of greenhouse gas

(GHG) emission and reducing global warming through substituting firewood for cooking, kerosene for lighting and cooking and chemical fertilizers. A study was undertaken to calculate (1) global warming mitigation potential (GMP) and thereby earning carbon credit of a family size biogas plant in India, (2) GMP of the existing and target biogas plants in the country and (3) atmospheric pollution reduction by a family size biogas plant. The GMP of a family size biogas plant was 9.7 t CO_2 equiv. $year^{-1}$ and with the current price of US \$10 t^{-1} CO_2 equiv., carbon credit of US \$97 $year^{-1}$ could be earned from such reduction in greenhouse gas emission under the clean development mechanism (CDM). A family size biogas plant substitutes 316 L of kerosene, 5,535 kg firewood and 4,400 kg cattle dung cake as fuels which will reduce emissions of NOx, SO_2, CO and volatile organic compounds to the atmosphere by 16.4, 11.3, 987.0 and 69.7 kg $year^{-1}$, respectively. Presently 3.83 million biogas plants are operating in the country, which can mitigate global warming by 37 Mt CO_2 equiv. $year^{-1}$. Government of India has a target of installing 12.34 million biogas plants by 2010. This target has a GMP of 120 Mt CO_2 equiv. $year^{-1}$ and US \$1,197 million as carbon credit under the CDM. However, if all the collectible cattle dung (225 Mt) produced in the country is used, 51.2 million family size biogas plants can be supported which will have a GMP of 496 Mt of CO_2 equiv. $year^{-1}$ and can earn US \$4,968 million as carbon credit. The reduction in global warming should encourage policy makers to promote biogas technology to combat climate change and integration of carbon revenues will help the farmers to develop biogas as a profitable activity. [Rajasthan has 17.44 million cattle, 5.44 million buffalo, that produce 26.53 million tonnes dung per year. Since dung is lost during collection (30%) and used for construction (1–9%) it has to be deducted from total production to arrive at available dung for biogas production. Thus, available dung for biogass production in **Rajasthan** is 17.78 million tonnes per year. If all the collectible cattle dung produced in the **Rajasthan** is used, 4.04 million family size biogas plants can be supported which will have a GMP of 39.1 Mt of CO_2 equiv. $year^{-1}$ and can earn US \$391.9 million (Rs. 1763.55 crore) as carbon credit]. India supports the largest bovine (cattle + buffalo) population (286.22 million) of the world.]

137. Phadtare, N. R. (2000). **"Sharp decrease in summer monsoon strength 4000-3500 cal yr B.P. in the central higher Himalaya of India based on pollen evidence from alpine peat**." Quaternary Research **53**(1): 122-129.

Age-constrained pollen data and magnetic susceptibility of an alpine peat profile from the Garhwal Higher Himalaya display a continuous record of climate and monsoon trends for the past 7800

yr. About 7800 cal yr B.P., dominance of evergreen oak (*Quercus semecarpifolia*), alder (Alnus), and grasses in the pollen record reflect a cold, wet climate with moderate monsoon precipitation. From 7800 to 5000 cal yr B.P., vegetation was progressively dominated by conifers, indicating ameliorated climate with a stronger monsoon. A warm, humid climate, with highest monsoon intensity, from 6000-4500 cal yr B.P. represents the mid-Holocene climatic optimum. Between 4000 and 3500 cal yr B.P., the abundance of conifers sharply decreased, with the greatest increase in evergreen oak. This trend suggests progressive cooling, with a decrease in the monsoon to its minimum about 3500 cal yr B.P. Two relatively minor cold/dry events at ca. 3000 and 2000 cal yr B.P. marked step-wise strengthening of the monsoon until ca. 1000 cal yr B.P. After a cold/dry episode that culminated ca. 800 cal yr B.P., the monsoon again strengthened and continued until today. A sharp decrease in temperature and rainfall at 4000-3500 cal yr B.P. represents the weakest monsoon event of the Holocene record. This cold/dry event correlates with proxy data from other localities of the Indian subcontinent, Arabian Sea, and western Tibet.

138. Potdar, M. B., S. S. Pokharna, V. N. Sridhar. (1993). **"Response of vegetation in the Thar Desert to monsoon rainfall: an investigation using NOAA AVHRR and meteorological data."** Journal of Arid Environments **25**(1): 19-26.

The study of dependence of vigor and senescence of desert vegetation on monsoon rainfall is important in understanding the desert ecosystem. In the study reported here the response of vegetation in the **Thar Desert** to the monsoon rainfall is investigated using multitemporal NOAA AVHRR data of post-monsoon period and meteorological data of 1990 monsoon period for the nine core districts of western **Rajasthan**. The temporal profiles show three distinct characteristics and these have been interpreted in terms of cumulative soil-moisture budget during monsoon. The results show that the vigour and the senescence of desert vegetation are strongly correlated with the root zone cumulative soil moisture and somewhat weakly correlated with the cumulative soil moisture at the deeper layers. The plot of normalized difference vegetation index (a surrogate measure of vigour of vegetation) at the end of the monsoon vs. average annual rainfall shows the existence of three ecological zones.

139. Prabhakar, S. V. R. K. and R. Shaw (2008). **"Climate change adaptation implications for drought risk mitigation: A perspective for India."** Climatic Change **88**(2): 113-130.

Evidence is growing to suggest that climate change clearly has implications for drought vulnerable India with studies projecting future possible reductions in monsoon related rainfall in the country. The existing drought risk mitigation and response mechanisms (including path of drought response in the state of **Rajasthan**) were looked into and gaps were identified by drawing lessons from previous disasters and response mechanisms. In absence of reliable climate predictions at the scales that make them useful for policy level planning, the emphasis was on identifying no-regret adaptation options those would reduce current vulnerabilities while mainstreaming the adaptation in the long run. The most notable climate change implications for the drought vulnerable India are the enhanced preparedness with due emphasis to the community based preparedness planning, reviewing the existing monsoon and drought prediction methodologies, and establishing drought monitoring and early warning systems in association with a matching preparedness at the input level.

140. Prasad, R., R. S. Mertia, P. Narain. (2004). "**Khadin cultivation: a traditional runoff farming system in Indian Desert needs sustainable management**." Journal of Arid Environments **58**(1): 87-96.

Khadin cultivation is a typical land use system of runoff farming followed since 15th century in 100-200 mm rainfall zone in Jaisalmer district of western **Rajasthan**. The soils in khadins are fertile due to regular settlement of fine sediments brought down by the runoff water and their potential for producing food grain is well recognized for securing a dependable harvest. However, the productivity from khadin cultivation remains low due to many factors. Some of the thrust areas and strategies for better management of khadins with higher productivity on sustainable basis include designing of new khadins with provision of spillway, recycling of excess stored water for either growing of crops in down reaches or for life saving irrigation in upper reaches and adjoining land, conservation measures to ensure availability of soil moisture to crops over a period of their duration, standardization of fertilizer requirement of different crops and adoption of multi-production systems such as agroforestry, fisheries, etc. To predict the crop productivity from khadin cultivation on sustainable basis; there is a need to generate data on productivity in relation to rainfall, catchment area, ponding depth, status of conserved moisture, and soil fertility for different crops over a period of time for low, normal and above-normal monsoon. Future research has to be directed to develop short-duration varieties whose water requirement matches with the availability of conserved moisture in khadins. Emphasis has

to be given on integration of multipurpose woody perennials like *Acacia nilotica* (Linn.) Del sub sp. indica, *Prosopis cineraria* (Linn.) Druice, *Zizyphus mauritiana* Lamk. etc., and fruit bearing plant species such as *Cordia myxa* Linn. and *Phoenix dactylifera* Linn. for enhancing productivity from khadin cultivation.

141. Prasad, S., S. Kusumgar, S. K. Gupta. (1997). "**A mid to late Holocene record of palaeoclimatic changes from Nal Sarovar: a palaeodesert margin lake in western India**." Journal of Quaternary Science **12**(2): 153-159.

With a view to obtain palaeoclimatic data from a climatically sensitive region authors have studied core samples from Nal Sarovar, a large shallow lake lying within the palaeodesert margin of Thar in western India. A high-resolution record extending back to ca. 6.6 ka BP has been reconstructed. The data indicate that, in the past, climate has varied from drier to wetter than present on time-scales of few hundreds to few thousands of years. There are, however, significant differences on the timing of these wet and dry periods, when compared with the available data from lakes farther north, in **Rajasthan**. Further, it looks unlikely that during the 6.6 ka the catchment areas of Nal Sarovar experienced such a significant increase in rainfall as has been suggested for the **Rajasthan** lakes. Interestingly, drier periods in Nal Sarovar data appear to correlate well with periods of glacier expansion in Eurasia indicating that the palaeoclimatic variations recorded in Nal Sarovar are a regional feature.

142. Purohit, I. and P. Purohit (2010). "**Techno-economic evaluation of concentrating solar power generation in India**." Energy Policy **38**(6): 3015-3029.

The Jawaharlal Nehru National Solar Mission (JNNSM) of the recently announced National Action Plan on Climate Change (NAPCC) by the Government of India aims to promote the development and use of solar energy for power generation and other uses with the ultimate objective of making solar competitive with fossil-based energy options. The plan includes specific goals to (a) create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022; (b) create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership; (c) promote programmes for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022, (d) achieve 15 million m^2 solar thermal collector area by 2017 and 20 million by 2022, and (e) deploy 20 million solar lighting systems for rural areas by 2022. The installed capacity of grid interactive solar power projects were 6 MW until

October 2009 that is far below from their respective potential. In this study, a preliminary attempt towards the technical and economic assessment of concentrating solar power (CSP) technologies in India has been made. To analyze the techno-economic feasibility of CSP technologies in Indian conditions two projects namely PS-10 (based on power tower technology) and ANDASOL-1 (based on parabolic trough collector technology) have been taken as reference cases for this study. These two systems have been simulated at several Indian locations. The preliminary results indicate that the use of CSP technologies in India make financial sense for the north-western part of the country (particularly in **Rajasthan** where the financial performance indicators for the CSP systems are attractive for most of the locations such as Jaisalmer, Bikaner, Barmer, Kota, Jodhpur, Jobner, Udaipur, and Jaipur). Moreover, internalization of secondary benefits of carbon trading under clean development mechanism of the Kyoto Protocol further improves the financial feasibility of CSP systems at other locations considered in this study. It may be noted that the locations blessed with annual direct solar radiation more than 1800 kWh/m^2 are best recommended for installation of CSP systems. The results obtained can be used as preliminary indicators for identifying niche areas for immediate/short-term utilization of solar energy for concentrating solar power generation in India.

143. Ragab, R. and C. Prudhomme (2002). "**Climate change and water resources management in arid and semi-arid regions: Prospective and challenges for the 21st century**." Biosystems Engineering **81**(1): 3-34.

This is a global analysis which also provides data on the larger areas of **Thar Desert** (India–Pakistan–Afghanistan). Estimations suggest that the annual average increase in temperature in Thar Desert ranges from 1·75 to 2·5°C, ranging from 1·5 to 2·25°C in winter and from 2 to 2·5°C in summer. Annual average precipitation is shown to decrease by 5–25% in the region. The winter will have values closer to the annual average but the summer will have more decrease and most of the region will see a decrease closer to 25%. To address the challenges, two approaches are needed: increasing the efficiency with which current needs are met and increasing the efficiency with which water is allocated among different uses. In addition, non-conventional sources of water supply such as reclaimed, recycled water and desalinated brackish water or seawater is expected to play an important role.

144. Raje, D. and P. P. Mujumdar (2010). "**Reservoir performance under uncertainty in hydrologic impacts of climate change**." Advances in Water Resources **33**(3): 312-326.

Relatively few studies have addressed water management and adaptation measures in the face of changing water balances due to climate change. The current work studies climate change impact on a multipurpose reservoir performance and derives adaptive policies for possible future scenarios. The method developed in this work is illustrated with a case study of Hirakud reservoir on the Mahanadi river in Orissa, India, which is a multipurpose reservoir serving flood control, irrigation and power generation. Climate change effects on annual hydropower generation and four performance indices (reliability with respect to three reservoir functions, viz. hydropower, irrigation and flood control, resiliency, vulnerability and deficit ratio with respect to hydropower) are studied. Outputs from three general circulation models (GCMs) for three scenarios each are downscaled to monsoon streamflow in the Mahanadi river for two future time slices, 2045-65 and 2075-95. Increased irrigation demands, rule curves dictated by increased need for flood storage and downscaled projections of streamflow from the ensemble of GCMs and scenarios are used for projecting future hydrologic scenarios. It is seen that hydropower generation and reliability with respect to hydropower and irrigation are likely to show a decrease in future in most scenarios, whereas the deficit ratio and vulnerability are likely to increase as a result of climate change if the standard operating policy (SOP) using current rule curves for flood protection is employed. An optimal monthly operating policy is then derived using stochastic dynamic programming (SDP) as an adaptive policy for mitigating impacts of climate change on reservoir operation. The objective of this policy is to maximize reliabilities with respect to multiple reservoir functions of hydropower, irrigation and flood control. In variations to this adaptive policy, increasingly more weightage is given to the purpose of maximizing reliability with respect to hydropower for two extreme scenarios. It is seen that by marginally sacrificing reliability with respect to irrigation and flood control, hydropower reliability and generation can be increased for future scenarios. This suggests that reservoir rules for flood control may have to be revised in basins where climate change projects an increasing probability of droughts. However, it is also seen that power generation is unable to be restored to current levels, due in part to the large projected increases in irrigation demand. This suggests that future water balance deficits may limit the success of adaptive policy options.

145. Rajendran, K. and A. Kitoh (2008). **"Indian summer monsoon in future climate projection by a super high-resolution global model."** Current Science **95**(11): 1560-1569.

The impact of future climate change on the Indian summer monsoon has been investigated using a super high-resolution global

general circulation model. The model with approximately 20-km mesh horizontal resolution can resolve features on finer spatial scales, which were till now resolved by employing highresolution regional models. Regional models are known to have high dependency on the lateral boundary forcing and significant inability to represent regionalglobal scale interactions comprehensively. Another advantage of the 20-km global model is its fidelity in representing the regional distribution of the presentday monsoon rainfall. Super high-resolution future scenario for the Indian summer monsoon shows widespread but spatially varying increase in rainfall over the interior regions and significant reduction in orographic rainfall over the west coasts of Kerala and Karnataka and the eastern hilly regions around Assam. Over these regions, the drastic reduction of wind by steep orography predominates over the moisture build-up effect (that causes enhanced rainfall over other parts) in reducing the rainfall. This indicates that monsoon rainfall is strongly controlled by parameterized physics and high-resolution processes which need to be resolved with adequately high resolution. The model projects substantial, spatially heterogeneous increase in both extreme hot and heavy rainfall events over most parts of India by the end of the century. While fine-scale surface moisture feedbacks influence the response of extreme hot events, extreme precipitation is influenced by fine-scale orography, evaporation, moisture content and circulation. Thus, the results indicate that consideration of fine-scale processes is critical for accurate assessment of local and regionalscale vulnerability to climate change. [A signal of increased vegetation activity of India from 1981 to 2001 observed using satellite-derived fraction of absorbed photosynthetically active radiation. Evaporation is enhanced over these regions since the soil moisture content also increases in these areas (not shown) as a consequence of the increased rainfall. In contrast, comparatively weaker enhancement is seen over regions with reduced future rainfall, such as **Rajasthan**, Jammu–Kashmir and parts of Assam, Arunachal Pradesh, Manipur, Meghalaya and Mizoram.]

146. Rajput, D. S. and H. Tripathi (2005). **"Camel husbandry practices followed by Raika pastoralists under semi-intensive system in Bikaner district of Rajasthan."** Indian Journal of Animal Sciences **75**(11): 1307-1313.

Camel husbandry practices among 60 selected Raika pastoral families in 4 villages of Bikaner district of **Rajasthan** were studied. Most of the Raikas were utilizing traditional tools and techniques in camel management and keeps their camels in semi-intensive system. Their camel management practices were unique under severe drought and harsh climatic conditions. Feeding system comprised locally

grown leguminous fodder crops (moth chara, muffali chara and guar phalgati) as common roughages, while concentrates and salt were offered in low quantities than the scientific recommendations. Raika pastoralists were well versed with camel breeding practices and preferred natural service for breeding over the artificial insemination. Camels in the region are kept in the open areas irrespective of the season, however, they were protected in the extreme winter. They preferred traditional system of treatment for camel health care over the veterinary doctors. Camel husbandry was an important source of income among all families. Marketing of camel was the major trade to earn/generate money among pastoralists. Generally adult male camels were sold after the age of 5 years. Raikas never sell either the camel milk or products. It was mostly consumed at home as such or after preparing kheer, otherwise it was supplied to the neighbours or hospitals for patients at free of cost.

147. Rajput, D. S. and H. Tripathi (2005). **"Migratory pattern of Raika Pastoralists in Bikaner district of Rajasthan."** Journal of Camel Practice and Research **12**(1): 53-56.

This paper provides an overview on migration system of Raika Pastoralists in Bikaner district of Rajasthan. Raika of this region fall in category of semi nomadic pastoralists because they adopt migration for passing adverse climatic condition specially drought that frequently occurs in this region and cause heavy economic and biological losses to camel farmers. They follow no particular route and area for migration. The route is selected after thorough discussion with family members and other pastoralists in the village and according to the probability of getting good pasture and more water for animals. Though, they face many problems during migration but they perceive it as essential for saving their camels and other livestock from adverse situation.

148. Ram, B. and A. S. Kolarkar (1993). **"Remote sensing application in monitoring land-use changes in arid Rajasthan."** International Journal of Remote Sensing **14**(17): 3191-3200.

Land-use changes in various parts of arid **Rajasthan** were identified and mapped on reconnaissance, semi-detailed and detailed levels using multidate remotely-sensed data, supported with field check and secondary informations. During the last three decades the net sown area in arid Rajasthan has increased by 36% while current and long fallows have declined by 29 and 41%, respectively. The net irrigated area has increased by 140%. Forest and pastures become highly degraded although their areas have increased to some extent. Land-use changes that occurred during the 1979 and 1990 floods are also discussed. In addition, the advantages and limitations of remote

sensing and their comparison with traditional methods are also highlighted.

149. Ram, K. A., A. Tsunekawa, D. K. Saha and T. Miyazaki (1999). **"Subdivision and fragmentation of land holdings and their implication in desertification in the Thar desert, India."** Journal of Arid Environments **41**(4): 463-477.

Analysis of data of the household level in Khabra Kalan village in the Thar desert of India that the land holding size is halved every 20-30 years due to subdivision of land holdings. The subdivision is caused by the equal sharing among sons at the time of inheritance based on the succession laws, and attributed to the increase in the village population. The shrinking land holdings resulted in a shortfall of food on small farms; 12% in cereals and 42% in pulses, promoted continuous cultivation and the increase of monoculture, and deteriorated the land productivity through its effect on the soil fertility and land management.

150. Ramachandra, T. V. and Shwetmala (2009). **"Emissions from India's transport sector: Statewise synthesis."** Atmospheric Environment **43**(34): 5510-5517.

A decentralized emission inventories are prepared for road transport sector of India in order to design and implement suitable technologies and policies for appropriate mitigation measures. Globalization and liberalization policies of the government in 90's have increased the number of road vehicles nearly 92.6% from 1980-1981 to 2003-2004. These vehicles mainly consume non-renewable fossil fuels, and are a major contributor of green house gases, particularly CO_2 emission. This paper focuses on the statewise road transport emissions (CO_2, CH_4, CO, NOx, N_2O, SO_2, PM and HC), using region specific mass emission factors for each type of vehicles. The country level emissions (CO_2, CH_4, CO, NOx, N_2O, SO_2 and NMVOC) are calculated for railways, shipping and airway, based on fuel types. In India, transport sector emits an estimated 258.10 Tg of CO_2, of which 94.5% was contributed by road transport (2003-2004). Among all the states and Union Territories, Maharashtra's contribution is the largest, 28.85 Tg (11.8%) of CO_2, followed by Tamil Nadu 26.41 Tg (10.8%), Gujarat 23.31 Tg (9.6%), Uttar Pradesh 17.42 Tg (7.1%), **Rajasthan** 15.17 Tg (6.22%) and, Karnataka 15.09 Tg (6.19%). These six states account for 51.8% of the CO_2 emissions from road transport.

151. Ramanathan, V. and Y. Xu (2010). **"The Copenhagen Accord for limiting global warming: Criteria, constraints, and available**

avenues." Proceedings of the National Academy of Sciences **107**(18): 8055-8062.

At last, all the major emitters of greenhouse gases (GHGs) have agreed under the Copenhagen Accord that global average temperature increase should be kept below 2 °C. This study develops the criteria for limiting the warming below 2 °C, identifies the constraints imposed on policy makers, and explores available mitigation avenues. One important criterion is that the radiant energy added by human activities should not exceed 2.5 (range: 1.7–4) watts per square meter (Wm^{-2}) of the Earth's surface. The blanket of man-made GHGs has already added 3 (range: 2.6–3.5) Wm^{-2}. Even if GHG emissions peak in 2015, the radiant energy barrier will be exceeded by 100%, requiring simultaneous pursuit of three avenues: (i) reduce the rate of thickening of the blanket by stabilizing CO_2 concentration below 441 ppm during this century (a massive decarbonization of the energy sector is necessary to accomplish this Herculean task), (ii) ensure that air pollution laws that reduce the masking effect of cooling aerosols be made radiant energy-neutral by reductions in black carbon and ozone, and (iii) thin the blanket by reducing emissions of short-lived GHGs. Methane and hydrofluorocarbons emerge as the prime targets. These actions, even if we are restricted to available technologies for avenues ii and iii, can reduce the probability of exceeding the 2 °C barrier before 2050 to less than 10%, and before 2100 to less than 50%. With such actions, the four decades we have until 2050 should be exploited to develop and scale-up revolutionary technologies to restrict the warming to less than 1.5 °C.

152. Ramesh, R. (2001). "**High resolution Holocene monsoon records from different proxies: An assessment of their consistency**." Current Science **81**(11): 1432-1436.

Available high resolution quantitative monsoon reconstructions for the Holocene period in the Indian region are compared to assess for consistency among the proxy records. There is a good concordance among three different monsoon proxies from western India: (a) Pollen-based reconstruction of annual rainfall in **Rajasthan** from a sediment core in lake Lunkaransar, (b) stable carbon isotope variations in organic carbon from another core from the same lake, and (c) stable oxygen isotopic variations in surface-dwelling foraminifera from a sediment core in the coastal eastern Arabian Sea. While this is reassuring, the degree of concordance diminishes when records from widely separated sites in the Indian region are compared. Possible causes for this inconsistency are discussed, perhaps the most important among them being the large

spatial variations in monsoon rainfall over the Indian region, apparent in modern instrumental records. There is a need to assess the temporal variance of this geographical variability before multiproxy quantitative monsoon rainfall reconstructions can be integrated as a single time series (somewhat akin to the modern All India Summer Monsoon Rainfall time series compiled by the India Meteorological Department). Such an effort can serve to test and improve palaeoclimate/palaeomonsoon models.

153. Ramesh, R., and Yadava, M. G. (2005). "**Climate and water resources of India**." Current Science **89**(5): 818-824.

Authors attempt to synthesize available quantitative, precisely dated and high-resolution palaeorecords of the South Asian summer monsoon from different natural archives, highlighting their similarities and differences. Authors distinguish between the palaeorecords of monsoon winds and monsoon rainfall and underscore the importance of quantitative rainfall reconstruction using the amount effect in monsoon rainfall, which has been demonstrated based on actual measurements. Predicting the future of water resources of India in the context of Global Change, intimately coupled with the variations of monsoon, depends on how well we understand the palaeomonsoon.

154. Ramesh, R., R. A. Jani, R. Bhushan. (1993). **"Stable isotopic evidence for the origin of salt lakes in the Thar Desert**." Journal of Arid Environments **25**(1): 117-123.

There are a number of salt lakes in and around the **Thar Desert**, India. A few major ones are Sambhar, Kuchaman, Didwana in **Rajasthan** and Kharaghoda in Gujarat. There have been a number of hypotheses concerning the origin of these salt lakes. One of them is that these lakes are relicts of the Tethys Sea that existed in this region before the collision of the Indian and Eurasian plates around 70 Ma ago. Authors have tested this hypothesis by collecting more than 50 brine and fresh water samples from in and around these lakes and measuring their stable isotope ratios of oxygen ($\delta^{18}O$) and hydrogen (δD). These results show no evidence for the above hypothesis of marine origin for these lakes. On the contrary, the isotopic data are consistant with the hypothesis that the water in these lakes are of meteoric origin and the salt is locally derived by the weathering of rocks in this region. A simple model calculation shows that these lakes behave as terminal lakes; they receive water during the short monsoon season (June-September) and evaporate during the rest of the year (there is no outflow and evaporation is equal to inflow). The model calculated saturation $\delta^{18}O$ value for these lakes is in good agreement with the mean measured value indicating that

these lakes are formed by accumulation and evaporation cycles fed by local precipitation.

155. Rao, A. S. (2009). "**Climate and microclimate changes influencing the fauna of the hot Indian arid zone**." In, C. Sivaperuman, Q. H. Baqri, G. Ramaswamy and M. Naseema (eds.) Faunal Ecology and Conservation of the Great Indian Desert. Berlin Heidelberg, Springer: pp. 13-23.

The Indian hot arid zone, situated largely in western **Rajasthan** and Kachchh of Gujarat, is subjected to frequent droughts and famines causing high stress on flora and fauna. Annual rainfall in the region varies from 100 to 500 mm and air temperatures from −5.0 to 48°C. Soil temperature decreases sharply by 10–20°C from the surface to depths below 20 cm, particularly during the summer months, improving life conditions in the burrows of rodents, snakes, reptiles, insects, etc. Drought occurrence in the Thar region has amounted to 47–62% of the last century, causing widespread economic loss due to crop failures, and promoting a substantial migration of human and livestock populations in search of better living conditions. The high densities of human and livestock populations in the region further aggravate the depletion of natural resources and impact on biodiversity. The introduction of irrigation to the **Thar Desert** via the construction of the Indira Gandhi Canal has resulted in substantial man-induced changes in the microclimate, flora and fauna of the area, due to the conversion of grasslands into irrigated cultivated lands. Notably, extensive long-term irrigation has not only increased vegetation in Sri Ganganagar but it has also improved the rainfall by 1.2 mm/year. Where irrigation has been introduced less extensively in Jaisalmer District, however, only a slight increase in annual rainfall (0.2 mm/year) has been observed, while there has been no significant change in long-term rainfall in irrigation-free Bhuj. Land-use changes continue to influence the microclimate, rainfall patterns and fauna of the Thar region.

156. Rathore, J. S. (2004). "**Drought and household coping strategies: A case of Rajasthan.**" Indian Journal of Agricultural Economics **59**(4): 689-708.

Most parts of the state of **Rajasthan** are drought-prone. Vulnerability of the people to drought varies from region to region depending on its intensity. Yet, the people living in the affected villages managed to eke out a living and sustain themselves during the drought period of 1999-2002. The role of the state, however marginal, is undeniable in managing the scarcity conditions. However, the most important factor is the strategies adopted by the people on the basis of an understanding of the constraints as well as the

potential of the drought-prone environment. This paper attempts to look into the impact of drought on various aspects of rural lives in order to understand the strategies and practices adopted by the drought affected people to cope with drought. The 'coping' strategies discussed are: (i) Livestock based farming system, (ii) Crop-mix and cropping pattern, (iii) Tree management and agro-forestry and (iv) Migration.

157. Ravindranath, N. H. and P. Balachandra (2009). "**Sustainable bioenergy for India: Technical, economic and policy analysis**." Energy **34**(8): 1003-1013.

India's energy challenges are manifested through growing demand for modern energy carriers, a fossil fuel dominated energy system facing a severe resource crunch, the need for creating access to quality energy for the large section of deprived population, vulnerable energy security, local and global pollution regimes and the need for sustaining economic development. Renewable energy is considered as one of the most promising alternatives. India has been implementing one of the largest renewable energy programmes in the world. Among the renewable energy technologies, bioenergy has a large diverse portfolio including efficient biomass stoves, biogas, biomass combustion and gasification and process heat and liquid fuels. India has also formulated and implemented a number of innovative policies and programmes to promote bioenergy technologies. However, according to some preliminary studies, the success rate is marginal compared to the potential available. This limited success is a clear indicator of the need for a serious reassessment of the bioenergy programme. Further, a realization of the need for adopting a sustainable energy path to address the above challenges will be the guiding force in this reassessment. This paper considers the potential of bioenergy to meet the rural energy needs: (1) biomass combustion and gasification for electricity; (2) biomethanation for cooking energy (gas) and electricity; and (3) efficient wood-burning devices for cooking. The paper focuses on analysing the effectiveness of bioenergy in creating this rural energy access and its sustainability in the long run through assessing: the demand for bioenergy and potential that could be created; technologies, status of commercialization and technology transfer and dissemination in India; economic and environmental performance and impacts; bioenergy policies, regulatory measures and barrier analysis. The assessment aims at presenting bioenergy as an integral part of a sustainable energy strategy for India. The results indicate that bioenergy technology (BET) alternatives compare favourably with the conventional ones. The cost comparisons show that the unit costs of BET alternatives are in the range of 15–187%

of the conventional alternatives. The climate change benefits in terms of carbon emission reductions are to the tune of 110 T C per year provided the available potential of BETs are utilized.

158. Ravindranath, N. H. and R. Sukumar (1998). **"Climate change and tropical forests in India."** Climatic Change **39**(2/3): 563-581.

India has 64 Mha under forests, of which 72% are tropical moist deciduous, dry deciduous, and wet evergreen forest. Projected changes in temperature, rainfall, and soil moisture are considered at regional level for India under two scenarios, the first involving greenhouse gas forcing, and the second, greenhouse gas forcing and sulfate aerosols. The projections use available predictive models. Under the former scenario a general increase in temperature and rainfall in all regions is indicated. This could potentially result in increased productivity, and change forest type boundaries along altitudinal and rainfall gradients, with species migrating from lower to higher altitudes and the drier forest types being transformed to moister types. The aerosol scenario, however, indicates a more modest increase in temperature and a decrease in precipitation in central and northern India, which would considerably stress the forests in these regions. Although India seems to have stabilized the area under forest since 1980, anthropogenic stresses such as livestock pressure, biomass demand for fuelwood and timber, and the fragmented nature of forests will all affect forest response to changing climate. Thus, forest area is unlikely to expand even if climatically suitable, and will probably decrease in parts of northeast India due to extensive shifting cultivation and deforestation. A number of general adaptation measures to climate change are listed (forest protection and conservation, reforestation and biomass conservation).

159. Ravindranath, N. H., N. V. Joshi, R. Sukumar and A. Saxena (2006). **"Impact of climate change on forests in India."** Current Science **90**(3): 354-361.

Global assessments have shown that future climate change is likely to significantly impact forest ecosystems. The present study makes an assessment of the impact of projected climate change on forest ecosystems in India. This assessment is based on climate projections of Regional Climate Model of the Hadley Centre (HadRM3) using the A2 (740 ppm CO_2) and B2 (575 ppm CO_2) scenarios of Special Report on Emissions Scenarios and the BIOME4 vegetation response model. The main conclusion is that under the climate projection for the year 2085, 77% and 68% of the forested grids in India are likely to experience shift in forest types under A2 and 62 scenario, respectively. Indications are a shift

towards wetter forest types in the northeastern region and drier forest types in the northwestern region in the absence of human influence. Increasing atmospheric CO_2 concentration and climate warming could also result in a doubling of net primary productivity under the A2 scenario and nearly 70% increase under the B2 scenario. The trends of impacts could be considered as robust but the magnitudes should be viewed with caution, due to the uncertainty in climate projections. Given the projected trends of likely impacts of climate change on forest ecosystems, it is important to incorporate climate change consideration in forest sector long-term planning process. [The projected climate (average for 2071–2100) for the more moderate B2 scenario is both wetter (an average increase of about 220 mm) and warmer (an average increase of about 2.9°C) compared to the HadRM3 baseline. The corresponding values of increase for the more extreme A2 scenario are about 300 mm and 4.2°C respectively. The mean annual precipitation for the projected values for B2 scenario turns out to be 1314 mm and the projected mean temperature is about 25.6°C. Northwestern India is likely to become drier, while northeastern India is likely to become much wetter. The temperature increase in northwestern India is also much more than that in the northeast. Southern and southeastern parts of India are likely to experience only a moderate increase in temperature. There are two maps showing these results].

160. Robbins, P. (1998). "**Authority and environment: institutional landscapes in Rajasthan, India.**" Annals of the Association of American Geographers **88**(3): 410-435.

To date, there have been few systematic assessments of the role of social institutions-rules, norms, and systems of authority and power-in creating and reconfiguring natural environments. In the desert grass and shrub lands of Rajasthan, India, where multiple, contending institutions govern village resources in a state of legal pluralism, the need for such research is pressing. Here, state political interventions vie against traditional common and semiprivate rule arrangements for control of valuable pasture and forest resources. This paper introduces an authority-centered theoretical vocabulary for such an analysis and reviews research conducted during 1993-1994 comparing four institutional forms to assess the role of institutions in configuring resource extraction decisions made by producers and in creating distinct and distinguishable biotic conditions. The study results demonstrate that responses to authority differ along axes of gender, caste, and class and so lead to varied decisions by producers. Each institutional form gives rise to a statistically significant pattern of annual and perennial herb distribution and of tree species occurrence. The location of

enforcement, whether central or locl, is shown to be less important than the breadth of authority forms controlling the resource. The results hold implications for future work in cultural/political ecology and for global change research. They also call into question any a priori assumptions of the superiority of either state of local resource management regimes.

161. Robbins, P. (1998). "**Nomadization in Rajasthan, India: migration, institutions, and economy**." Human Ecology **26**(1): 87-112.

Amidst a global trend toward settlement, the incidence of pastoral nomadism is increasing in the Marwar region of western **Rajasthan**, India, with a regional livestock population increasingly on the move, sometimes turning to year-round nomadism in order to meet the demands of seasonal pasturage. The notion that common property grazing resources have disappeared amid unprecedented growth of the regional herd cannot explain the observed trends. Rather, changing institutional and economic patterns are creating new contexts for strategic movement. The transition into migratory strategies has developed from the decline of key village social institutions which manage pasture and forest land, the profits earned from intensification in an increasingly capitalized market, and the benefits of migration in the form of the herd's increased reproductive capacity. Producers in this population increase their access to markets and the reproductive rate of their herd through long, annual migration. Nomadism in this setting is therefore a general adaptation to changes in the socioeconomic conditions of the region, although differential resource endowments account for the range of strategies.

162. Rodell, M., I. Velicogna and J. S. Famiglietti (2009). "**Satellite-based estimates of groundwater depletion in India**." Nature **460**: 999-1002.

Groundwater is a primary source of fresh water in many parts of the world. Some regions are becoming overly dependent on it, consuming groundwater faster than it is naturally replenished and causing water tables to decline unremittingly. Indirect evidence suggests that this is the case in northwest India, but there has been no regional assessment of the rate of groundwater depletion. Here authors use terrestrial water storage-change observations from the NASA Gravity Recovery and Climate Experiment satellites and simulated soil-water variations from a data-integrating hydrological modelling system to show that groundwater is being depleted at a mean rate of 4.0 plus-minus 1.0 cm yr^{-1} equivalent height of water (17.7 plus-minus 4.5 km^3 yr^{-1}) over the Indian states of **Rajasthan**, Punjab and Haryana (including Delhi). During the study period of

August 2002 to October 2008, groundwater depletion was equivalent to a net loss of 109 km^3 of water, which is double the capacity of India's largest surface-water reservoir. Annual rainfall was close to normal throughout the period and the other terrestrial water storage components (soil moisture, surface waters, snow, glaciers and biomass) did not contribute significantly to the observed decline in total water levels. Although observational record is brief, the available evidence suggests that unsustainable consumption of groundwater for irrigation and other anthropogenic uses is likely to be the cause. If measures are not taken soon to ensure sustainable groundwater usage, the consequences for the 114,000,000 residents of the region may include a reduction of agricultural output and shortages of potable water, leading to extensive socioeconomic stresses.

163. Rohilla, P. P., K. Chand and D. C. Mathur (2004). **"Livestock rearing practices in arid fringes of Rajasthan."** Annals of Arid Zone **43**(2): 185-190.

A survey on livestock rearing practices in Pali district of **Rajasthan** was conducted during January to December, 2002. The livestock maintained by farmers are local/non-descript types except a few. A significant increase in buffalo population in last five years indicated of its vital role in improving dairy farmers' economy in arid region also. The nutritional status of the livestock was not satisfactory due to scarcity of feed/fodder in the drought year. Majority of the livestock owners were ignorant about balanced feeding. No elaborate housing was provided to animals in rural areas, except a temporary protection during winter months. Livestock owners were not much concerned about animal health, especially cattle, which they consider uneconomical. Proper marketing facilities for animal products like goat and camel milk, meat and wool lacking.

164. Roy, M. and H. D. Venema (2002). **"Reducing risk and vulnerability to climate change in India: the capabilities approach."** Gender and Development **10**(2): 78-83.

This paper argues that the ability of women to adapt to climate change pressures will be enhanced by using the 'capabilities approach' to direct development efforts. By using this approach, women will improve their wellbeing, and act more readily as agents of change within their communities. This argument is supported by previous research on gender and livelihoods, and a study conducted in rural India. Examples are based on the experiences of poor, rural women in India, who are particularly vulnerable to climate change impacts. Their survival is dependent on their being able to obtain many essential resources from their immediate environment. However, these women lack many of the requirements for wellbeing, such as

access to health care, literacy, and control over their own lives. Gaining these would reduce their vulnerability to their changing environmental circumstances.

165. Roy, P. D., W. Smykatz-Kloss and O. Morton (2008). "**Geochemical zones and reconstruction of late Holocene environments from shallow core sediments of the Pachapadra paleo-lake, Thar Desert, India**." Geochemistry **68**(3): 313-322.

Lithostratigraphy, mineralogy, major and trace element concentrations, carbon and sulphur contents are investigated from a shallow depth profile from Pachapadra paleo-lake, **Thar Desert**, north-western India, to understand the phases of paleo-hydrology and paleo-limnology. Based on the geochemical proxies (Na/Al, Si/Al, Zr/Al and Ca/Mg) and evaporite mineralogy, the depth profile is divided into three geochemical zones of variable sediment–water interaction, evaporation and aeolian activity. The sub-recent zone (I) enriched in halite (NaCl) indicates low chemical weathering and higher aeolian input. The intermediate relatively humid zone II is enriched in major elements, trace elements and calcite ($CaCO_3$) and reflects higher chemical weathering in the catchments. Zone III is enriched in gypsum ($CaSO_4 \cdot 2H_2O$) and characterised by lower chemical weathering, higher aeolian activity and evaporation.

166. Roy, P. D., Y. C. Nagar, N. Juyal, W. Smykatz-Kloss and A. K. Singhvi (2009). "**Geochemical signatures of Late Holocene paleo-hydrological changes from Phulera and Pokharan saline playas near the eastern and western margins of the Thar Desert, India**." Journal of Asian Earth Sciences **34**(3): 275-286.

Stratigraphical, mineralogical, geochemical and optical dating methods were used to reconstruct paleo-hydrological changes in two playas (Phulera, 500 mm/a and Pokharan, 200 mm/a) in near extremum climatic regions of the **Thar Desert**. Sediment successions in shallow profiles from Phulera and Pokharan in **Rajasthan** contain three and four stratigraphic units, respectively, each with characteristic geochemical properties. These units reflect changes in chemical weathering, detrital input, salinity and provide a measure of the changes in precipitation (i.e. monsoon) through time. Sediments from Pokharan suggest short rainfall events during ca. 6.6–4 ka, relatively stable fresh water (higher and persistent rainfall) regime during 4–2.3 ka, and a hyper saline (low rainfall) condition during 2.3–1.1 ka. Sediments at Phulera, record hyper saline (low rainfall) lacustrine conditions during <2.3 ka to >1.4 ka. Higher abundance of gypsum in Pokharan (2.3–1.1 ka) and proto-dolomite in Phulera (2.3–1.4 ka) are nearly synchronous and reflect enhancement of salinity. Selenite crystals in Pokharan and large desiccation cracks in buried

horizons at Phulera reflect desiccation of playas at ca. 2 ka. Both playas progressively became less saline after 1.4 ka. Given the regional nature of this record, these changes are attributed to fluctuation of the monsoon over the Indian sub continent.

167. Roy, S. S. (2009). "**A spatial analysis of extreme hourly precipitation patterns in India**." International Journal of Climatology **29**(3): 345-355.

Station level hourly precipitation data from 1980 to 2002 spread across the Indian subcontinent were analysed for trends in extreme hourly precipitation events. The analyses were conducted for the main seasons of winter, dry-summer, and wet-summer monsoon seasons, respectively. The results of the study indicated rising trends in extreme heavy precipitation events, mostly in the high-elevation regions of the northwestern Himalaya as well as along the foothills of the Himalaya extending south into the Indo-Gangetic basin. In general, the lowest positive trends to slightly neutral to negative trends in extreme precipitation events were observed during the winter season, while stronger positive trends were found for both dry-summer and wet-summer monsoon seasons. Along the west coast, the southern part experienced a declining trend, whereas the northern section of the coast experienced an increasing trend of extreme precipitation events. Most of Deccan Plateau extending towards south central coastal regions of the subcontinent also experienced a positive trend in the occurrence of extreme heavy precipitation events. The dry-summer season over the subcontinent typically extends between March and May. The highest annual temperatures for the whole year are experienced during this season across the entire subcontinent, led by northwestern India's **Rajasthan**.

168. Roy, S. S. and R. C. B. Jr (2009). "**Evaluation of extreme precipitation indices using daily records (1910-2000) from India**." Weather **64**(6): 149-152.

Authors assembled daily precipitation records for 93 stations in India with more than 95%-complete records over the period 1910–2000 and computed 23 different annual extreme precipitation indices that have been used recently in the literature. Study found that many of the popular indices summarize variances related to the magnitude of annual precipitation, and that this dimension in the data has a moderate upward trend over the 85-year study period. This result was in conformity with the findings of previous study about the trends in extreme weather events across the Indian subcontinent (Sen Roy and Balling, 2004).

169. Saifuddin and Iqbaluddin (2000). "**Quaternary signatures of paleo-humidity in arid zone, Rajasthan, India**." Journal of Arid Environments **45**(2): 151-158.

The arid zone of **Rajasthan** had a humid past. The present communication records provide evidence of paleo-humidity from the Ajmer district in **Rajasthan** manifested as channel conglomerates and karst development in the marble rocks within the arid landscape, which suggests that a humid phase existed in the Luni Basin during the Quaternary period in **Rajasthan**. The present find of Quaternary signatures of paleo-humidity suggests that the humid phase in the **Thar Desert** extended beyond the Saraswati drainage basin up to the Luni basin, covering the entire Trans-Aravalli region.

170. Saini, H. S., S. K. Tandon, S. A. I. Mujtaba and N. C. Pant (2005). "**Lake deposits of the northeastern margin of Thar Desert: Holocene: Palaeoclimatic implications**." Current Science **88**(12): 1994-2000.

The understanding of past climates, particularly Holocene climate, changes in continental settings is significant for improving the predictive capability of models used for building future climate change scenarios. Continental sedimentary systems such as lake and river basins support large agricultural communities; even the desert margins support a substantial rural population. Therefore, understanding of the responses of these systems to future climate changes on decadal, century, and millennial scales needs to be strengthened in order to determine the varying limits of land, soil, water and vegetation resource structure on the demographic structure. In this context, authors document the lake/pond deposits of the northeastern margin of **Thar Desert** along a rainfall gradient (200-600 mm) from west to east (including dry arid Nohar–Bhadra area of **Rajasthan**). The potential of the lake deposits and the associated sedimentary facies for the reconstruction of post-Last Glacial Maximum climate history is discussed, and the need for developing a chronological database on this important archive of continental Holocene climate is recognized.

171. Saini, N., R. Kumar, B. D. Kiradoo, N. Singh, A. Bhardwaj and M. S. Sahani (2006). "**Camel rearing practices: A survey study in arid western agro-ecosystem of Rajasthan.**" Journal of Camel Practice and Research **13**(2): 179-184.

Camel rearing in northwestern arid region of **Rajasthan** was studied in 8 districts, falling in 5 agro climatic zones. Camels are reared based on traditional knowledge by utilising natural available resources and the main utilities are self domestic use, breeding and

selling purpose. Mostly camels are managed on rangelands, community land, restricted controlled pasture lands (*gochers* or *orans*). Traditional feeding constituting exclusively grazing plus providing some supplementation of leaves during lean period has shifted to grazing plus providing some additional local fodder to meet the dry matter requirement. Mineral mixture is not often given to camels. Majority of the camel keepers (60%) feed single type of local grown fodder whereas 39.0% farmers feed mixed dry fodder. Generally green forage is not offered except 23.4% farmers of Hanumangarh and Sriganganagar district and Rajgarh tehsil of Churu, a green belt area, who offer green chana fodder to their camels. Concentrate supplementation once a week is done only to debilitated camels (1 to 2 kg) against scientific recommendation of 2-3 kg/day. Irrespective of season, camels are generally kept in open housing system. Failure of availabilitiy of conventional flora and grazing resources due to frequent drought, shrinking of grazing land owing to fast urbanisation and restriction imposed by the forest department has forced camel breeders to offer some straw in addition to grazing in the rangeland thus, increasing cost of feed input.

172. Saint, K. (1988). **"Drought in the Aravallis."** Social Action **38**(2): 129-137.

The visible effects of drought in the Aravallis mountains, **Rajasthan**, are not different from the way Colonel Brooke had described them a century ago. However the coping mechanisms of the tribals have been weakened by deforestation and the destruction of their life support system. A long-term solution has to be worked out, not a short-term relief plan, which can be used as a mode of building up community assets to strengthen the weaker sections. In other words, what is needed is not drought relief but drought proofing.

173. Samant, S. (2007). **An exploration of the historic core along Lake Pichola in Udaipur.** 10th International Conference on Studies, Repairs and Maintenance of Heritage Architecture, STREMAH 2007, Prague.

The aim of this study is to develop an appreciation of the historic core along the eastern edge of Lake Pichola in Udaipur, which is a result of its unique climatic, social and topographical context, to chart the changes to this context, to draw attention to past patterns and to learn from them in the hope of influencing future developments. The study is limited to the historic core along the waterfront and its related structures along the eastern bank of Lake Pichola in Udaipur. The study demonstrated that the lake front is a result of evolution guided by dominant determinants such as socio-

economic hierarchy/structure, political and religious factors, climate, availability of materials and technology. The overall form, settlement pattern and the massing of buildings in Udaipur are dominated by its physical attributes and in consonance with the topography and landscape, and ordered by the generative force of its land form and the lake. It is, however, subject to severe developmental and environmental pressures as a result of intense tourism related and commercial activities, unwarranted and haphazard building activities, continuous neglect of residential properties, some of the historic fabric and surviving artefacts, and poor infrastructure. If this trend were to continue, the problems will intensify causing serious threat to this valuable environment, its urban spaces and exquisite edifices. Preservation of this waterfront, which plays a decisive role in solving critical urban, social and economic problems in this city, is vital. The main issues identified for consideration in this context were the preservation of existing traditions, conservation, sensitive and participatory planning and design, appropriate organization of street activities, continued adaptive reuse of buildings, provision of infrastructure and administrative structures to deliver the project, and creation of awareness and understanding amongst the local community.

174. Sanchez, P. A. (2000). **"Linking climate change research with food security and poverty reduction in the tropics**." Agriculture, Ecosystems & Environment **82**(1/3): 371-383.

A Consultative Group on International Agricultural Research (CGIAR) intercentre working group on climate change identified joint opportunities that take advantage of the comparative advantages of the CGIAR and the International Geosphere-Biosphere Programme. CGIAR centres will focus on adaptation and mitigation research in Developing Countries. A natural resource management approach is suggested, which consists of six steps: (1) identifying and quantifying the extent of food insecurity, rural poverty and resource degradation; (2) conducting technological and policy research; (3) optimizing the trade-offs between global environmental benefits and private farmer benefits; (4) extrapolating and disseminating results, including research on policy implementation; (5) assessing impact and (6) providing feedback. Two examples of current CGIAR research illustrate this approach. Agroforestry alternatives to slash and burn agriculture at tropical forest margins were identified and the trade-offs between carbon sequestration and farmer profitability provided options to policy makers. Land tenure problems were resolved with participatory policy research. Agroforestry practices sequester an additional 57 Mg C per ha. Soil nutrient capital is being replenished in subhumid tropical Africa, helping farmers to attain food security.

Afterwards when farmers shift to high-value tree or vegetable crop production, poverty is reduced. The transformation of low productivity croplands to sequential agroforestry is estimated to triple system carbon stocks in 20 years.

175. Sanghi, A. and R. Mendelsohn (2008). "**The impacts of global warming on farmers in Brazil and India**." Global Environmental Change **18**(4): 655-665.

How big a threat is global warming to climate-sensitive and economically important sectors such as agriculture in developing countries? How well will farmers be able to adapt to the threats of global warming? This paper attempts to shed light on these two important questions. A cross-sectional analysis is employed to estimate the climate sensitivity of agriculture in Brazil and India. Using panel data from both countries, the study measures how net farm income or property values vary with climate, and consequently, how farmers in India and Brazil react and adapt to climate. The estimated relationships are then used to predict the consequence of alternative climate scenarios. Global warming by the end of the next century could cause annual damages in Brazil between 1% and 39% and between 4% and 26% in India, although some of this effect may be potentially offset by carbon fertilization. These estimates do not factor into account climate-induced extreme weather events. The low-value wheat growing regions such as hot and dry districts of **Rajasthan** and Central India are damaged only slightly.

176. Sarkar, A., R. Ramesh, B. L. K. Somayajulu, R. Agnihotri, A. J. T. Jull, and G. S. Burr. (2000). "**High resolution Holocene monsoon record from the eastern Arabian Sea**." Earth and Planetary Science Letters **177**(3-4): 209-218.

Through stable oxygen and carbon analyses of rapidly accumulating sediment cores from the eastern Arabian Sea, authors show that the excess of evaporation over precipitation (E-P) steadily appears to have decreased during the last ~10000 to ~2000 years, most probably due to an increasing trend in the summer monsoon rainfall, contrary to the land-based paleoclimatic data from this region, which indicate onset of aridity around 4000 years ago. These results are consistent with the hypothesis that significant spatial variability in the monsoon rainfall observed today was persistent during most of the Holocene. Alternatively, the trend can be seen as an adjustment between two phases, one between ~10000 and ~6000 years ago of increasing precipitation and another between 3500 and 2000 years ago after the arid episode. Authors also report a significant ~700 year periodicity, similar to that reported recently from the South China Sea, indicating that the centennial/millennial scale

response of the Indian and Chinese monsoons to high latitude forcing may be alike.

177. Sathaye, J., P. R. Shukla and N. H. Ravindranath (2006). **"Climate change, sustainable development and India: Global and national concerns**." Current Science **90**(3): 314-325.

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. This paper addresses these challenges. Historically, the responsibility for greenhouse gas emissions' increase lies largely with the industrialized world, though the developing countries are likely to be the source of an increasing proportion of future emissions. The projected climate change under various scenarios is likely to have implications on food production, water supply, coastal settlements, forest ecosystems, health, energy security, etc. The adaptive capacity of communities likely to be impacted by climate change is low in developing countries. The efforts made by the UNFCCC and the Kyoto Protocol provisions are clearly inadequate to address the climate change challenge. The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion of energy efficiency, renewable energy, forest conservation, reforestation, water conservation, etc. The issue of highest importance to developing countries is reducing the vulnerability of their natural and socio-economic systems to the projected climate change. India and other developing countries will face the challenge of promoting mitigation and adaptation strategies, bearing the cost of such an effort, and its implications for economic development.

178. Scanlon, B. R., A. Mukherjee, J. Gates, R. C. Reedy and A. K. Sinha. (2010). **"Groundwater recharge in natural dune systems and agricultural ecosystems in the Thar Desert region, Rajasthan, India."** Hydrogeology Journal **18**(4): 959-972.

Water and nutrient availability for crop production are critical issues in (semi)arid regions. Unsaturated-zone Cl tracer data and nutrient (NO_3 and PO_4) concentrations were used to quantify recharge rates using the Cl mass balance approach and nutrient availability in the Thar Desert, **Rajasthan**, India. Soil cores were collected in dune/interdune settings in the arid Thar Desert (near Jaisalmer) and in rain-fed (nonirrigated) and irrigated cropland in the semiarid desert margin (near Jaipur). Recharge rates were also simulated using unsaturated zone modeling. Recharge rates in

sparsely vegetated dune/interdune settings in the Jaisalmer study area are 2.7–5.6 mm/year (2–3% of precipitation, 165 mm/year). In contrast, recharge rates in rain-fed agriculture in the Jaipur study area are 61–94 mm/year (10–16% of precipitation, 600 mm/year). Minimum recharge rates under current freshwater irrigated sites are 50–120 mm/year (8–20% of precipitation). Nitrate concentrations are low at most sites. Similarity in recharge rates based on SO_4 with those based on Cl is attributed to a meteoric origin of SO_4 and generally conservative chemical behavior in these sandy soils. Recharge rates under rain-fed agriculture indicate that irrigation of 20–40% of cultivated land with 300 mm/year should be sustainable.

179. Shah, T. (2009). "**Climate change and groundwater: India's opportunities for mitigation and adaptation**." Environmental Research Letters **4**: 035005 doi: 10.1088/1748-9326/4/3/03500.

For millennia, India used surface storage and gravity flow to water crops. During the last 40 years, however, India has witnessed a decline in gravity-flow irrigation and the rise of a booming 'water-scavenging' irrigation economy through millions of small, private tubewells. For India, groundwater has become at once critical and threatened. Climate change will act as a force multiplier; it will enhance groundwater's criticality for drought-proofing agriculture and simultaneously multiply the threat to the resource. Groundwater pumping with electricity and diesel also accounts for an estimated 16–25 million mt of carbon emissions, 4–6% of India's total. From a climate change point of view, India's groundwater hotspots are western and peninsular India. These are critical for climate change mitigation as well as adaptation. To achieve both, India needs to make a transition from surface storage to 'managed aquifer storage' as the center pin of its water strategy with proactive demand- and supply-side management components. In doing this, India needs to learn intelligently from the experience of countries like Australia and the United States that have long experience in managed aquifer.

180. Shah, T. and K. V. Raju (2002). "**Rethinking rehabilitation: socio-ecology of tanks in Rajasthan, north-west India**." Water Policy **3**(6): 521-536.

In the arid and semi-arid Indian state of **Rajasthan**, tanks and ponds have been a mainstay of rural communities for centuries. This paper assesses a rehabilitation strategy proposed for 1200 large tanks. It argues that treating tanks only as flow irrigation systems is very likely to result in a flawed strategy. As the experience of NGOs work shows, Rajasthan's tanks belong more to the watershed development domain than to the irrigation domain and a strategy that views tanks

as multi-use socio-ecological constructs, and which recognizes varied stakeholder groups is more likely to enhance the social value of tanks.

181. Shanmugaratnam, N. (1996). **"Nationalisation, privatisation and the dilemmas of common property management in western Rajasthan."** Journal of Development Studies **33**(2): 163-187.

Since 1949, the Indian state of **Rajasthan** has experienced a series of land reforms and other policy interventions which tended to disregard the institutional needs of natural resource management in general and common property resource management in particular. Nationalisation of land and the creation of modern forms of private property for agricultural expansion along with rising population densities have caused continuous decline in availability of common property resources and undermined possibilities for collective action in the arid zone of **Rajasthan** which occupies a major part of the state. This article reviews the problem of common property resources management in **Rajasthan's** arid zone from a historical-institutional perspective and provides a microanalysis based on a household survey in two sets of villages. It concludes by highlighting the current dilemmas of common property resource management and indicating possible directions for policy intervention.

182. Sharma, B. R., K. V. Rao, K. P. R. Vittal, Y. S. Ramakrishna and U. Amarasinghe (2010). **"Estimating the potential of rainfed agriculture in India: Prospects for water productivity improvements."** Agricultural Water Management **97**(1): 23-30.

A detailed study comprising the 604 districts of India was undertaken to (i) identify dominant rainfed districts for major rainfed crops, (ii) make a crop-specific assessment of the surplus runoff water available for water harvesting and the irrigable area, (iii) estimate the efficiency of regional rain water use and incremental production due to supplementary irrigation for different crops, and (iv) conduct a preliminary economic analysis of water harvesting/supplemental irrigation to realize the potential of rainfed agriculture. A climatic water balance analysis of 225 dominant rainfed districts provided information on the possible surplus runoff during the year and the cropping season. On a potential (excluding very arid and wet areas) rainfed cropped area of 28.5 million ha, a surplus rainfall of 114 billion m^3 (Bm^3) was available for harvesting. A part of this amount of water is adequate to provide one turn of supplementary irrigation of 100 mm depth to 20.65 Mha during drought years and 25.08 Mha during normal years. Water used in supplemental irrigation had the highest marginal productivity and increase in rainfed production above 12% was achievable even under traditional practices. Under improved management, an average

increase of 50% in total production can be achieved with a single supplemental irrigation. Water harvesting and supplemental irrigation are economically viable at the national level. Net benefits improved by about threefold for rice, fourfold for pulses and sixfold for oilseeds. Droughts have very mild impacts on productivity when farmers are equipped with supplemental irrigation.

183. Sharma, C. and S. Chatterjee (2007). "**The past 26,000 years evolutionary history of Keoladeo National Park (Ghana), Rajasthan**." Current Science **92**(8): 1161-1165.

Pollen analysis of a 4.4 m trench dug out from the Keoladeo National Park (Bharatpur district, **Rajasthan**) situated on the western edge of the Gangetic Plains has revealed that around 26,000 yrs BP, the area was a thick forest dominated by Holoptelea under moist climate and good monsoon, reflecting an interstadial period. The next phase between 20,000 and 14,000 yrs BP had witnessed a barren zone with no trace of any pollen deposition. This could be attributed to poor preservation of pollen during the course of sedimentation, most likely due to the drying of the lake during the Last Glacial Maximum period. This was followed by favourable humid conditions and good vegetation cover in the region. Gradually this large lake turned into a wetland.

184. Sharma, K. D. (2009). "**Groundwater management for food security.**" Current Science **96**(11): 1444-1447.

There is a strong nexus among overutilization of groundwater, subsidized power utility, marketing, minimum support price and procurement policies. Improving competitiveness of water-guzzling crops in the groundwater surplus eastern India and less water-requiring commodities in overexploited northwest and south India through technology, marketing, incentives and disincentive interventions could rationalize the groundwater use. Grouping of major foodgrain-producing states according to the level of groundwater development in India (Haryana, Punjab and **Rajasthan**) suggests that groundwater in these areas is overexploited to the tune of 109–145%.

185. Sharma, S. (1995). "**Drought, mortality and social structure**." Environmental Education and Information **14**(1): 85-94.

The social aspects of drought-induced morbidity and mortality in India are analyzed in this study. Mortality trends in **Rajasthan** State in India in the 1980s were analysed to correlate the increased death rate with the drought of 1987. It is demonstrated that drought-induced malnutrition is the root cause of death. Sociologically, populations are divided into three sections--fragile, resilient and

potent--which are differently affected by droughts, the fragile section suffering worst.

186. Singh, A. K., J. Sing, K. K. Reddy, R. Singh. (2003). "**Drought proofing mechanism in Mahi command area through linear programming model: A case study**." Indian Journal of Agricultural Research **37**(3): 187-192.

A linear programming model was developed to formulate an optimal cropping pattern during drought years in the command area of the Mahi Bajaj Sagar irrigation project in Banswara district, **Rajasthan**, India. The study revealed that by judiciously using a minimum quantity (58.7% of normal usage) of irrigation water during drought years, feeding 58% of the cropping area with minimum investment (less by 40.9%), it would be possible to achieve food security. At the same time, cooperative societies and local credit institutions should be strengthened for better results.

187. Singh, G. (2004). "**Growth, biomass production, and soil water dynamics in *Acacia tortilis* plantation in relation to microhabitat and surface vegetation in the hot arid region of Indian desert.**" Arid Land Research and Management **18**(2): 153-169.

Growth and biomass production of *Acacia tortilis* was examined in relation to microtopography and *Dactyloctinium sindicum* as the surface vegetation. Bare dune (BD), vegetated dune (VD), bare dune plantation (BDP), vegetated dune plantation (VDP), bare flatland (BF), vegetated flatland (VF), bare flatland plantation (BFP), and vegetated flatland plantation (VFP) were the microhabitats identified on the basis of microtopography, vegetation, and plantation of *A. tortilis*. Soil water content (SWC) was 17% higher in flatland and 35% higher in nonplanted than those in dune and planted areas, respectively. A 6.9 and 9.4 mm lower soil water in VF and VFP, respectively, than in BF indicated that *D. sindicum* extracted and utilized soil water more efficiently. The growth and biomass were similar between BDP and BFP, which were greater ($p < 0.05$) than in VDP and VFP microhabitats. Competitive effect of *D. sindicum* reduced biomass of *A. tortilis* by 6% and 58% and led greater carbon allocation (27% and 38%) in stem in VDP and VFP compared to BDP and FWP microhabitats. Fibrous roots of *A. tortilis* were more in 0-30 cm soil layer of BDP and BFP, whereas they penetrated deeper soil layer in VDP and VFP habitats.*D. sindicum* biomass (shoot + root in 0-90 cm soil layer) was 22-39% higher in flatland compared to dune. It was 438 g m^{-2} in VF in 1998, whereas *A. tortilis* facilitated grass production in 1999 and 2000 in VFP. The results indicate that *D. sindicum* competes with *A. tortilis* and affects the

growth and biomass. Weeding and soil working is recommended to reduce competition and better growth in flatland.

188. Singh, G. (2004). **"Influence of soil moisture and nutrient gradient on growth and biomass production of *Calligonum polygonoides* in Indian desert affected by surface vegetation."** Journal of Arid Environments **56**(3): 541-558.

A field study was carried out on growth and biomass production of *Calligonum polygonoides* (L.) in different habitats to determine competitive interaction of *Dactyloctenium sindicum* grass for natural soil resources. Bare dune (BD), bare dune plantation (BDP), semistabilized dune plantation with *D. sindicum* (SDP), flatland without vegetation (FW), flatland with *D. sindicum* grass (FG) and flatland plantation with *D. sindicum* (FGP) were the habitats identified on the basis of micro-topography, presence of *D. sindicum* grass and plantation. Growth and biomass production of *C. polygonoides* were observed in relation to changes in biomass from surface vegetation, soil water content and nutrients. *D. sindicum* grass density and biomass were significantly ($P<0.01$) high in FG in 1998 whereas, in 1999 and 2000, FGP produced greater biomass. Soil organic matter, NH_4–N, NO_3–N, PO_4–P and K were comparatively greater in the habitats with *D. sindicum* in 1996. All the nutrients increased in 2000 except NO_3–N and the improvement was more in plantation. High ($P<0.01$) soil water content in FW and BD suggests that *D. sindicum* had extracted and utilized soil water more efficiently through its extensive root system in the remaining habitats. Soil water content increased in winter and coincided with plant senescence. Plant growth and biomass productions were significantly ($P<0.05$) less and grass production was greater in FGP. Contrasting result was obtained in BDP habitat in absence of *D. sindicum*. Difference in soil water content and nutrients seems to be the main cause for productivity differences of *C. polygonoides*. Lesser plant growth in FGP and SDP habitats was attributed to the competitive effect of *D. sindicum* grass, which seemed to have a stronger competitive effect on resource utilization. The differences in growth and biomass production accounted for the variation in *D. sindicum* grass density and root biomass, which was negatively correlated with growth increments and with soil water. The results indicate that surface vegetation affects the productivity of *C. polygonoides* altering availability of soil resources. Therefore, proper management to ensure water availability will be beneficial to enhance the productivity and the population of this species under afforestation programme.

189. Singh, G. (2009). **"Soil water dynamics, growth of Dendrocalamus strictus and herbage productivity influenced by**

rainwater harvesting in Aravalli hills of Rajasthan." Forest Ecology and Management **258**(11): 2519-2528.

Degraded Aravalli hills in western India require rehabilitation through resource conservation and afforestation for meeting the biomass needs of resource-poor tribes of the region. Rainwater harvesting treatments i.e., control, Contour trench (CT), Gradonie (G), Box trench (BT) and V-ditch (VD) were prepared in <10%, 10–20% and >20% slopes categories and *Dendrocalamus strictus* L. seedlings were planted in August 2005 with a view to conserve soil and water and increase the productivity of the hills. Soil water content (SWC), survival and height of *D. strictus* plants were highest ($P < 0.05$) in <10% slope and all these variables decreased with increase in slope. SWC increased by 27.45% and 25.68% in <10% and >20% slopes, respectively than in 10–20% slope. From lowest in control SWC increased by 11.95%, 20.21%, 17.61% and 11.49% in CT, G, BT and VD treatments, respectively. Growth variables were highest in VD plots but the increase in shoot number was highest (2.9-fold) in CT plots. Increase in effects of rainwater harvesting with time indicated by a change in production pattern from highest ($P < 0.05$) fresh and dry herbage in <10% slope in 2005 to 10–20% slope (24.66% and 26.09%) in 2006 and >20% slope (42.42% and 48.35%, respectively) in 2007. The increase in herbage was 1.17–2.40-fold in fresh and 1.20–2.52-fold in dry herbage over control. Highest ($P < 0.01$) production was in V-ditch plots. The treatments order for herbage production was C < CT < G < BT < VD. But the production was highest in BT in <10% and in V-ditch plots in 10–20 and >20% slopes. Conclusively, soil water status is affected by natural slope, stony soil surface and rainwater harvesting structures influencing seedling growth and herbage production. Box trench and V-ditch enhanced surface soil water facilitating herbage growth, whereas contour trench facilitated deep soil water storage, which was made available to the plants after monsoon. Thus rainwater harvesting practices enhanced vegetation cover and productivity of the degraded hills and can be replicated to conserve soil resource and increase biomass for rural poor of the region.

190. Singh, G. and T. R. Rathod (2002). **"Plant growth, biomass production and soil water dynamics in a shifting dune of Indian desert."** Forest Ecology and Management **171**(3): 309-320. A study was carried out to find suitable species and its combined surface vegetation with the aim of fast stabilization of dune and production of fuel and fodder from this highly stressed site. Seedlings of Acacia tortilis, Prosopis juliflora and Calligonum polygonoides species were planted on shifting dune and micro-windbreaks were erected to protect the seedlings from the drifting sand. Cassia angustifolia and

Cenchrus ciliaris were sown as treatment (vegetation type) to develop undercanopy vegetation. Vegetation types had no significant (P>0.05) effect on the growth of the species. However, growth of species differed significantly (P<0.001) and P. juliflora was the best performer to cover soil in a best way. C. polygonoides produced the highest biomass in the form of fuelwood utilizing minimum amount of soil water. There was an increase in SOM and soil available NH4-N due to plantation and vegetation type treatments. *C. polygonoides* with *C. ciliaris* was the best combination for fuel and fodder production, whereas combination with *C. angustifolia* was the best to control sand drift. Sowing of undershrubs and grass of local importance can also be done in advance to control the sand drift and burial of the planted seedlings. It will help in the improvement of soil conditions and control the sand drift when the seedlings attain greater height leaving bare the undercanopy soil.

191. Singh, G., N. Bala, K. K. Chaudhury and R. L. Meena (2003). "**Carbon sequestration potential of common access resources in arid and semi-arid regions of northwestern India**." Indian Forester **129**(7): 859-864.

A study was carried to observe the vegetation status of Common Access Resources (CARs) and carbon stock in some selected villages of 10 degraded sites in six ecozones namely degraded forest areas, land with scrub, gulliesand ravines, degraded pastureland, salt land and sand desertic with objective of strategic planning to improve their productivity. High vegetation status in Gujarat resulted greater carbon stock compared to that in **Rajasthan**. Carbon in the form of vegetation biomass ranged from 1.96 to 2.83 Mg ha^{-1} in Gujarat and 0.24 to 1.73 Mg ha^{-1} in **Rajasthan**. Soil carbon was 3.60 to 6.38 Mg ha^{-1} compared to 1.13 to 5.18 Mg ha^{-1} in Rajasthan being lowest in the sandy area of Mokal and Ramgarh. The potential of carbon sequestration in the CARs has been worked out to be 6.13 Mg ha-1 yr^{-1}. With this sequestration potential the CARs should be able to meet the local need for fuel fodder and small timber.

192. Singh, G., R. D. Joshi and A. B. Singh (1972). "**Stratigraphic and radiocarbon evidence for the age and development of three salt lake deposits in Rajasthan, India**." Quaternary Research **2**(4): 496-505.

A series of radiocarbon determinations have been carried out of lacustrine deposits contained in three playa basins, namely at Sambhar, Didwana and Lunkaransar, in **Rajasthan**, in conjunction with stratigraphical and palynological investigations. It is revealed that the lake deposits, which overlie thick beds of sand at each site, date back from early Holocene times (ca. 10,000 B.P.). The authors

present the radiocarbon evidence together with an outline of the stratigraphy of the deposits, and attempt to reconstruct the sedimentary sequence in the three basins since the beginning of the lacustrine phase. The significance of the more or less synchronous development in all the three playa basins is discussed with reference to postglacial climatic oscillations in northwest India.

193. Singh, G., R. D. Joshi, S. K. Chopra and A. B. Singh (1974). "**Late Quaternary history of vegetation and climate of the Rajasthan desert, India**." Philosophical Transactions of the Royal Society of London. B, Biological Sciences **267**(889): 467-501.

The results from stratigraphy, radiocarbon dating and pollen analysis of three salt-lake deposits at Sambhar, Lunkaransar and Didwana in western **Rajasthan**, and one freshwater lake deposit at Pushkar in the Aravalli Hills, are described in conjunction with pollen analysis of some archaeological soil samples from the Indus Valley site at Kalibangan in northern **Rajasthan**. The salt-lake deposits studied are stratigraphically divisible into (a) pre-lacustrine, (b) lacustrine and (c) post-lacustrine sections. The pre-lacustrine section is characterized by a thick bed of aeolian sand underlying lacustrine sediments, while the lacustrine and post-lacustrine sections are broadly circumscribed by laminated clay and nonlaminated silt respectively. The pollen record from the four lake profiles studied is divided into local pollen zones. Four regional pollen assemblage zones are delineated for the area west of the Aravalli Range in **Rajasthan**. The environmental history deduced from the pollen record is divisible into phases I-V, of which phases II-V follow the regional pollen assemblage zones. Phase I is stratigraphically determined, and is representative of severe arid environments under which the sand dunes, now stabilized, are suggested to have been active. The plant microfossils first appear in phase II with the deposition of lacustrine sediments dated to around 10000 B.P. The vegetation comprises an openland steppe which is rich in grasses, Artemisia and sedges and poor in halophytes. *Artemisia*, *Typha angustata*, *Mimosa rubicaulis* and *Oldenlandia*, which now grow under areas of comparatively higher average annual rainfall (above 50 cm), appear to have flourished in the semi-arid belt, while the first two plant taxa had encroached even as far as the arid belt, both suggesting that a general westward shift of the rainfall belts had taken place. Vegetation destruction through burning by man is suggested to have started together with the first occurrence of Cerealia-type pollen at about 7500 B.C. and continued thereafter throughout phases III and IV. The increase in swamp vegetation and the intensification of vegetation cover inland together with the maxima of all mesophytic elements in phase IV (ca. 3000 B.C. to ca. 1000 B.C.) indicate an

increase in the rainfall, apart from a short relatively drier time about 1800-1500 B.C. at Sambhar which correlates with the decline of the Indus culture in northwest India. Phase IV is immediately followed by aridity for which there is stratigraphic evidence that the salt lakes started drying. At Pushkar, there is evidence that the vegetation showed a marked change in the Aravallis. The onset of this aridity is suggested to have been widespread. The climate did not ameliorate until about phase V (? early centuries A.D. to present) at which time the Rangmahal culture perhaps flourished in **Rajasthan**, the remains of which imply good water supply. In conclusion it is suggested that the **Rajasthan** desert is primarily natural, its history punctuated by at least one more vegetated, humid period during the Holocene, the climatic control of which as indicated by the vegetation history consistent with climatic events elsewhere in the world.

194. Singh, G., R. J. Wasson and D. P. Agrawal (1990). **"Vegetational and seasonal climatic changes since the last full glacial in the Thar Desert, northwestern India**." Review of Palaeobotany and Palynology **64**(1-4): 351-358.

Studies are presented from Didwana salt lake, **Rajasthan**, India, showing a sequence of changes reflecting the history of summer and winter precipitation, in the **Thar Desert**, since the Last Full Glacial. Steppe vegetation, mainly of Chenopodiaceae/Amaranthaceae, grasses, Artemisia, Aerva and Ephedra, grew simultaneously with hypersaline lake conditions between about 20,000 and 13,000 yr B.P., indicating a considerably weakened summer monsoon and a higher winter precipitation than at present. A rise in precipitation is evidenced by the intermittent filling of the lake from c. 13,000 yr B.P. followed by nearly permanent freshwater between c. 9000 and 6000 yr B.P. The vegetation changed to a savanna grassland in which Prosopis cineraria formed the bulk of tree vegetation from c. 7500 yr B.P. Taxa indicative of both increased summer and winter precipitation rose during the mid-Holocene and declined during the late Holocene in harmony with a declining lake level. The lake became ephemeral c. 4000 yr B.P.

195. Singh, H., A. K. Singh, P. B. L. Chaurasia and A. Singh (2005). **"Solar energy utilization: A key to employment generation in the Indian Thar Desert."** International Journal of Sustainable Energy **24**(3): 129-142.

The Western Rajasthan commonly known as the 'Indian Thar Desert' is characterised by harsh climatic conditions with active dunal activities. Precipitation (150-420 mm/yr) is far lower than evapotranspiration potentials (1500-2000 mm/yr). Ground water is limited and often brakish and high (75-100 m) water table. Solar

intensity in the region varies from 5.85 to 6.44 kWh/m^2/day. Further, peculiarity of the region is that sun is available for 345-355 days in a year, the area being highly scarce in rainfall. On an average, rains occur only for 10.4-20.5 days in a year in the Thar Desert. Therefore, there is high scope to harness solar energy for useful purposes. Considering these solar energy technologies for entrepreneurs, the detailed cost analysis has been worked out and presented. With initial investment of Rs (Indian Rupees) 3.50 lakhs for solar drying projects for handling 60,000 kg fresh vegetables annually (300 working days/yr), the payback period and average net annual returns come to 2.17 years and Rs 1,43,753/-, respectively at 18% interest rate. However, in case of solar candle making system with initial investment of Rs 25,500/- for handling 18,750 kg raw paraffin wax annually (300 working days/yr) the payback period and net annual returns at 15%, interest rate come to about 3 months and Rs 1,12,793/-, respectively. Both these projects are highly profitable.

196. Singh, R. S., K. D. Sharma, Faroda, A. S. (1999). **"Climate change and its impact on drought and floods in Luni river basin of north-west arid India."** Journal of Agrometeorology **1**(2): 99-111.

To quantify possible climatic changes in the Luni Basin, long-term fluctuations and trends in rainfall within and in the adjoining areas were analysed for the period 1901-96 using weather data obtained from 12 stations including monthly and annual air temperatures of Jodhpur and Pali, **Rajasthan**, India. A significant rising trend in annual mean air temperature of 0.015 deg C year^{-1} in Jodhpur and 0.008 deg C year^{-1} in Pali was observed. Increasing (warming) trends were observed in the minimum air temperatures in Jodhpur during May, June and August. The annual precipitation ranged from 300 (in the northwest) to 600 mm (in the southeast) of the basin, more than 85% of which occurred from June to September. An increasing linear trend for the rainfall at 8 locations (with the highest (1.6 mm year^{-1}) in Ajmer) was observed during the study period.

197. Singh, S. K., A. K. Singh, B. K. Sharma and J. C. Tarafdar (2007). **"Carbon stock and organic carbon dynamics in soils of Rajasthan, India."** Journal of Arid Environments **68**(3): 408-421.

Soil carbon stock (CS), was estimated in the 0-25 and 0-100 cm soil depths of arid and semi-arid regions of **Rajasthan**. Carbon stock was 2.13 Pg in the 0-100 cm soil depth, of which 1.23 Pg was soil organic carbon and 0.90 Pg was soil inorganic carbon. The surface horizon (0-25 cm) stored 31% of the soil carbon stock. Soil carbon stocks were higher in Entisols (0.72 Pg or 33.6% of CS on 43.6% of the land area) and Aridisols (0.70 Pg or 32.7% of CS on

28.9% of the land area) than in Inceptisols (0.61 Pg or 28.6% of CS on 24.01% of the land area), Alfisols (0.015 Pg or 0.007% of CS on 0.76% of the land area) and Verisols (0.105 Pg or 0.005% of the CS on the 3.2% of the land area). Torripsamments, Haplocambids and Haplustepts together held 80% of CS and 86.9% of soil organic carbon stock, whereas Haplocambids, Petrocalcids and Haplustepts comprised 72% inorganic carbon stock. Soil organic carbon density (SOC) ranged from 4000 to 7000 kg/km^2 in Haplustalfs, Haplusterts, Haplustepts and Torripsamments, while its inorganic counterpart (SIC) was of higher range (10,000-19,000 kg/km^2) in Petrocalcids, Haplocalcids, Halpogypsids and Torrifluents. Under scrub vegetation of semi-arid **Rajasthan** the mean SOC in the 0-25 cm and 0-100 cm depths were 170 and 203.9 kg/km^2, respectively. In the arid region with similar situation the mean SOC was 5.5 and 14.0 kg/km^2, respectively. Excessive tillage and intensive cultivation in semi-arid region reduced soil organic carbon density from 60 kg/km^2 under single cropping to 10.5 kg/km^2 under double cropping. Subsistence farming in the arid region maintained 47 kg/km^2 SOC under croplands. SOC declined regularly from 1975 to 2002 in the arid region. A multiple linear regression model that includes rainfall together with tillage, silt, clay, available water capacity (AWC) and period of canopy cover accounted for 97% of the variation in soil organic carbon density for arid regions. The regression model further pointed out that a 4200-4600 kg/km^2/year SOC could be sequestered in untilled soils of the arid region, which have year-round canopy cover.

198. Singh, V. S., D. N. Pandey and P. Chaudhry (2010). "**Urban Forests and Open Green Spaces: Lessons for Jaipur, Rajasthan, India**." RSPCB Occasional Paper No. 1/2010. Jaipur, Rajasthan, India, Rajasthan State Pollution Control Board**:** pp. 23.

In an era of global climate change and rapid urbanization, innovations on governance of urban systems are critically required as 50% people are now living in less than 3% of the earth's urbanized terrestrial surface. Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Both policy and science now emphasize the critical necessity of green areas within urban social-ecological systems. Here, authors review the present status of urban forestry across the world, and draw lessons that can be applied for the governance of urban green spaces during the development of Jaipur as a world-class city in **Rajasthan**. There is a wide variation both in coverage as well as per capita availability of green spaces. There are, however, some discernible trends emerging from cities renowned for their urban green spaces: approximately 20 to 30%

coverage of the total geographical area, and 15 to 25 m^2 urban green spaces per capita. World Health Organization suggests ensuring at least a minimum availability of 9 m^2 green open space per city dweller. Finally, authors provide strategies and lessons for connecting science to decision-making aimed at creating multifunctional landscapes to enhance urban resilience and human well-being.

199. Singhvi, A. K. and A. Kar (2004). "**The aeolian sedimentation record of the Thar desert**." Proceedings of the Indian Academy of Sciences, Earth and Planetary Sciences **113**(3): 371-401.

A review of the aeolian sedimentary record of the **Thar desert** is presented. This includes a regional survey of the major dune forms, their genesis and their relationship to climate and other regional landforms. A key aspect of this work is the chronometry of the dunes using luminescence methods. Luminescence dating of sand has enabled quantification of the duration of the phases of sand aggradation and quiescence, time scales of dune migration and the dating of pedogenic carbonates. Authors demonstrate that the conventional wisdom of synchronicity of dune aggradation with glacial epoch is not true in the context of Thar sands and here only a short duration window of opportunity existed for dune aggradation. Luminescence ages further suggest that this window occurred during a transitional climatic regime from glacial to interglacial about 4-10 ka after the glacial epoch. Other inferences included are that: (i) the aeolian activity in the Thar began over > 150 ka, resolving that Thar is not of anthropogenic origin as suggested previously; (ii) the present spatial extent of the aeolian activity in the Thar is in a contracted stage compared to that in the geological past, which refutes the arguments on its rapid north-eastward expansion; (iii) the current dune migration rates in areas of significant human-induced disturbances are much higher than during the geological past; (iv) the monsoon activity in the Thar varied significantly, from being minimal during the isotopic marine stages 4 and 2 to being close to the present during stage 3; (v) on shorter time scales the dune activities correlated with the lacustrine records of the region with a phase difference of a few centuries and a periodicity of ~1500 years; (vi) the sand aggradation climate in the southern margin in Gujarat gradually shrank northwards such that in general dunes older than 10 ka are seen in the extreme southern margin and dunes younger than 2 ka ages occur mostly in the western part of Rajasthan.

200. Sinha, R., D. Stueben, Z. Berner. (2004). "**Palaeohydrology of the Sambhar Playa, Thar Desert, India, using geomorphological and sedimentological evidences**." Journal of the Geological Society of India **64**(4): 419-430.

The Sambhar Playa in western **Rajasthan**, India has been studied to understand its tectono-geornorphologic evolution and pallaeohydrological reconstruction. The playa basin originated due to tectonic movements during the Quaternary, and was deepened by large scale deflation during and periods. A dense network of relict drainage reflects abundant supply of water and sediments during wetter phases. A deep core (similar to23 m) raised from the center of the playa indicates an alternation of clastic and evaporitic sediments. Mineralogical assemblages and the geochemical characteristics have been used to decipher the palaeohydrological conditions in the region for a period extending over 25 ka. Evaporite mineralogy shows a major change in brine chemistry at similar to5 m depth, the lower part being rich in gypsum and the upper part completely devoid in gypsum. The vertical profile shows a correlation between Na/Al ratio, delta(18)O values of carbonates, MgO/(MgO+CaO) ratio of insoluble fraction and dolomite content. Authors interpret these trends as changes in evaporation/inflow ratio which in turn would reflect low/high stands of the lake.

201. Sinha, R., W. Smykatz-Kloss, D. Stüben, S.P. Harrison, Z. Berner and U. Kramar. (2006). "**Late Quaternary palaeoclimatic reconstruction from the lacustrine sediments of the Sambhar playa core, Thar Desert margin, India**." Palaeogeography, Palaeoclimatology, Palaeoecology **233**(3-4): 252-270.

The Sambhar playa in **Rajasthan**, India, located at the eastern fringe of the **Thar Desert**, records multiple phases of clastic- and evaporite-dominated deposition as revealed from a 23 m deep core drilled in the center of the playa. Seven evaporite facies, identified from the mineralogical data, reflect variable brine chemistry throughout the history of the playa. The complete absence of gypsum-rich facies in the upper 5 m and dominance of carbonate- and gypsum-rich facies in the lower parts of the core reflect fluctuations in salinity level induced by climate change. Stable isotope data on carbonates (δ18O values) correlate with the [MgO/(MgO + CaO)] ratio, geochemical ratios (Na/Al, Na/Ti, Na/K) and the evaporite mineralogy. These data, coupled with AMS chronology of the organic fraction of the core sediments, have been integrated to interpret evaporation/inflow ratios which reflect humid and arid climatic conditions. This data reconstruct the palaeoclimatic fluctuations in the Thar Desert margin for the last 30 ka and show significant spatial variation from the available lacustrine records from the **Thar Desert**. The Sambhar playa does not show any evidence of complete desiccation throughout its history although authors record arid phases during the LGM and between ca. 7500 and 6800 years.

202. Sirohi, S. (2007). **"CDM: Is it a 'win–win' strategy for rural poverty alleviation in India?"** Climatic Change **84**(1): 91-110.

India is perceived to be one of the most attractive Non-Annex I countries for CDM project development. There are more than 350 projects in the CDM pipeline, largely in the areas of renewable energy, energy efficiency in industries and fossil fuel switching. This paper examines the socio-economic component of sustainable development commitments of the CDM projects to see if they can make any impact on rural poverty in India, since the goal of poverty alleviation lies at the core of the country's development priorities. The study concludes that CDM is not contributing to rural poverty alleviation to any notable extent. Nearly all the projects have a business orientation and are not directed to the development of rural poor. Even the renewable energy projects will have limited role in up-liftment of the masses below poverty line due to their weak resource base. For CDM to emerge as a "win–win" strategy for poverty alleviation projects should be aimed at the rural communities and designed to accelerate agricultural growth in the rainfed regions of the country. Due to a number of economic and administrative reasons, geographically, CDM project activities are concentrated in the states of Karnataka, Andhra Pradesh and Tamil Nadu in southern India; **Rajasthan**, Gujarat and Maharashtra in the west and the northern state of Punjab. Spatial distribution of CDM projects and rural poverty in **Rajasthan** suggests that Rajasthan has 11 % of all CDM projects in India and the incidence of rural poverty: 1999–00 is 13.74 %. These include Biomass Power Project at Kalpataru Energy Venture Private Limited, Bayana Tahsil, Bharatpur District, Rajasthan; and Bundled Wind power project in Jaisalmer, **Rajasthan**.

203. Sivakumar, M., H. Das and O. Brunini (2005). **"Impacts of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics."** Climatic Change **70**(1): 31-72.

The arid and semi-arid regions account for approximately 30% of the world total area and are inhabited by approximately 20% of the total world population. Issues of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics of the world were examined and discussion under each of these issues had been presented separately for Asia, Africa and Latin America. Over land regions of Asia, the projected area-averaged annual mean warming is likely to be 1.6 ± 0.2 ∘C in the 2020s, 3.1 ± 0.3 ∘C in the 2050s, and 4.6 ± 0.4 ∘C in the 2080s and the models show high uncertainty in projections of future winter and summer precipitation. Future annual warming across Africa is projected to

range from 0.2 ∘C per decade to more than 0.5 ∘C per decade, while future changes in mean seasonal rainfall in Africa are less well defined. In Latin America, projections indicate a slight increase in temperature and changes in precipitation.

204. Sivakumar, S. and E. Kerbart (2004). "**Drought, sustenance and livelihoods: 'akal' survey in Rajasthan**." Economic and Political Weekly **39**(3): 285-294.

This article presents findings from a survey conducted in **Rajasthan**, India in March-April 2003, when the 'maha akal', the drought, was at its peak over large parts of rural **Rajasthan** and the government-initiated relief works were yet to make an impact. Covering 122 hamlets in 56 panchayats across nine districts, the report examines the manifestations of drought in people's everyday lives, specifically the ways food and water shortages impact men, women and children. It also examines the long-run impact of drought on people's assets (particularly livestock) and livelihoods and the coping strategies they adopt. It is concluded that drought may be a one-time occurrence but the effects are far-reaching and deep. In **Rajasthan**, it has reached a point where livelihood means are becoming persistently elusive. It is also apparent that relief programmes can at best bring some 'patchwork' respite, posing as a temporary cure.

205. Smit, B., I. Burton, R.J.T. Klein, R. Street (1999) "**The science of adaptation: A framework for assessment**." Mitigation and Adaptation Strategies for Global Change **4**(3-4): 325-352.

This paper outlines what is meant by "adaptation" to climate change, and how it might be addressed in the IPCC Assessments. Two roles of adaptation in the climate change field are identified: adaptation as part of impact assessment (where the key question is: what adaptations are likely?), and adaptation as part of the policy response (where the central question is: what adaptations are recommended?). The concept of adaptation has been adopted in several fields including climate impact assessment and policy development, risk management, and natural hazards research. A framework for systematically defining adaptations is based on three questions: (i) adaptation to what? (ii) who or what adapts? and (iii) how does adaptation occur? The paper demonstrates that, for adaptation purposes, climate extremes and variability are integral parts of climate change, along with shifts in mean conditions. Attributes for differentiating adaptations include purposefulness, timing, temporal and spatial scope, effects, form and performance. The framework provides a guide for the treatment of adaptation in

the IPCC assessments, both in the assessment of impacts and in the evaluation of adaptive policy options.

206. Staubwasser, M., F. Sirocko, P. M. Grootes, and M. Segl. (2003). "**Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability**." Geophysical Research Letters **30**(8): 1425.

Planktonic oxygen isotope ratios off the Indus delta reveal climate changes with a multi-centennial pacing during the last 6 ka, with the most prominent change recorded at 4.2 ka BP. Opposing isotopic trends across the northern Arabian Sea surface at that time indicate a reduction in Indus river discharge and suggest that later cycles also reflect variations in total annual rainfall over south Asia. The 4.2 ka event is coherent with the termination of urban Harappan civilization in the Indus valley. Thus, drought may have initiated southeastward habitat tracking within the Harappan cultural domain. The late Holocene drought cycles following the 4.2 ka BP event vary between 200 and 800 years and are coherent with the evolution of cosmogenic ^{14}C production rates. This suggests that solar variability is one fundamental cause behind Holocene rainfall changes over south Asia.

207. Stiefel, J. M., A. M. Melesse, M. E. McClain, R. M. Price, E. P. Anderson and N. K. Chauhan (2009). **"Effects of rainwater-harvesting-induced artificial recharge on the groundwater of wells in Rajasthan, India."** Hydrogeology Journal **17**(8): 2061-2073.

In light of the increasing deterioration of groundwater supplies in Rajasthan, India, rainwater harvesting practices in southern Rajasthan were studied to determine the effects of artificially recharged groundwater on the supply and quality of local groundwater. A physical and geochemical investigation utilizing environmental tracers ($\delta^{18}O$ and Cl^-), groundwater level and groundwater quality measurements, and geological surveys was conducted with two objectives: (1) to quantify the proportion of artificially recharged groundwater in wells located near rainwater harvesting structures and (2) to examine potential effects of artificial recharge on the quality of groundwater in these wells. A geochemical mixing model revealed that the proportion of artificial recharge in these wells ranged from 0 to 75%. Groundwater tracer, water table, and geological data provided evidence of complex groundwater flow and were used to explain the spatial distribution of artificial recharge. Furthermore, wells receiving artificial recharge had improved groundwater quality. Statistical analysis revealed a significant difference between the water quality in these wells and wells determined not to receive artificial recharge, for electrical

conductivity and $SO4^{-}$. The findings from this study provide quantitative evidence that rainwater harvesting structures in southern Rajasthan influence the groundwater supply and quality of nearby wells by artificially recharging local groundwater.

208. Subramaniam, A. R. and G. S. L. H. Prasada Rao (1980). **"Climatic study of water balance, aridity and droughts in Rajasthan state (Bikaner, Jaipur, Jhalawar)."** Annals of Arid Zone **19**(4): 371-377.

Climatological water balances are presented for three stations: Bikaner, Jaipur, and Jhalawar. They extend over the period 1969-1976. The basis of the paper is the Aridity Index (the ratio of annual water deficit to water need). The index has shown considerable year to year variability.

209. Sudha, P., H. I. Somashekhar, S. Rao and N. H. Ravindranath (2003). **"Sustainable biomass production for energy in India."** Biomass and Bioenergy **25**(5): 501-515.

In this paper, availability of land, various biomass production options, productivity rates, financial viability, investment required to produce biomass for energy and the barriers to biomass production are analysed. The scenarios considered for estimating the biomass potential are incremental biomass demand, sustainable biomass demand and the full biomass demand. Under these scenarios, two situations namely no increase in cropland by 2010 and increase in cropland by 10% over 1995 area have been considered. The land available for biomass production ranges from 9.6 to 36.5 (million hectare) Mha under the different scenarios. Annually 62-310 Mt of wood could be generated from the surplus land, after meeting all the requirements of biomass, such as domestic fuelwood, industrial wood and sawnwood, with an investment of Rs168-780 billion. An electricity generation potential of 62-310 TWh (one Terra Watt hour equals one billion kilo watt hour) annually is estimated. The key barriers to produce biomass sustainably for energy are lack of commercial demand for wood for energy, lack of financial incentives, low productivity of plantations, land tenurial barriers and lack of institutions to integrate biomass production for energy and bioenergy utilities.

210. Sudha, P. and N. H. Ravindranath (1999). **"Land availability and biomass production potential in India."** Biomass and Bioenergy **16**(3): 207-221.

Availability of land and the potential for biomass production in India to meet various demands for biomass, including modern bioenergy are assessed. This is estimated by considering the various

demands on land and its suitability. The biomass production potential of energy plantations is assessed for different agro-ecological zones. The total woody biomass production is estimated to be 321 Mt, based on biomass productivity in the range 2 to 17 t/ha/yr for the different agro-ecological zones and considering the conservative estimate of 43 Mha (million hectare) land availability for biomass production. A surplus of 231 Mt (million tones) of biomass (after meeting the increased demand for fuelwood and timber by the year 2010) is estimated to be available for energy, which has an electricity generation potential of 231 TWh. As a first step, only the feasible physical potential of biomass production is assessed, along with an analysis of barriers. The potential costs and benefits of biomass production strategy are not analysed.

211. Sukumar, R. (2000). **"Climate and ecosystem change: what does it mean for biodiversity conservation in India?"** Journal of the Indian Institute of Science **80**(6): 609-618.

Climate change as a consequence of human activity such as emission of greenhouse gases into the atmosphere is now a distinct possibility according to the assessment of the Intergovernmental Panel on Climate Change. During the 21st century climate change can be expected to make impacts on ecosystems and biodiversity on a global scale. In this paper, author briefly reviews the implications of climate change for forest and wildlife conservation in India. Outputs from general circulation models of temperature and precipitation changes over India are examined in the context of possible impacts on forests. A regional model of climate and vegetation change in Nilgiri Biosphere Reserve of south India is presented. Implications of this model for conservation of various vegetation types and endemic species such as the tahr (*Hemitragus hylocrins*) are discussed. Some adaptation strategies are outlined.

212. Swain, A. M., J. E. Kutzbach and S. Hastenrath (1983). **"Estimates of holocene precipitation for Rajasthan, India, based on pollen and lake-level data."** Quaternary Research **19**(1): 1-17.

A pollen profile obtained from lake sediments at Lunkaransar, Rajasthan, in northwest India was used along with a pollen-climate calibration function to estimate past precipitation. Between 10,500 and 3500 yr B.P., the estimated precipitation was about 500 mm/yr, or about 200 mm/yr above the modern value. A model was used for the energy and hydrologic budget of a lake basin and lake at Sambhar (located 240 km SE of Lunkaransar) to calculate that a 200 mm/yr increase in rainfall above the modern amount would have raised the lake level about 20 m above the modern level. Topographic charts

and satellite imagery provided some evidence in support of an enlarged paleolake of that elevation, but field exploration would be required to confirm the size and date of a former lake. After about 3500 yr B.P., the Lunkaransar profile indicated a desiccated lake bed; because no pollen was preserved, the pollen-climate calibration function was of no use for estimating the amount of the precipitation decline. A reduction of precipitation of about 200 mm/yr below the modern amount was estimated from the energy and hydrologic budget for paleolake Sambhar by assuming that the lake was one-tenth of its present size during the dry interval.

213. Swamy, M. and S. Bhattacharya (2006). **"Budgeting anthropogenic greenhouse gas emission from Indian livestock using country-specific emission coefficients."** Current Science **91**(10): 1340-1353.

Greenhouse gas (GHG) emissions from the livestock sector are confined to enteric fermentation and manure management. The present inventory is focused on estimation of GHGs using countryspecific emission factors for ruminants based on Indian Feeding Standards as a measure of gross energy intake. The thrust is on uncertainty reduction by adopting country-specific animal performance data leading to the development of more refined emission factors. The estimated GHG emission is 9.0 Tg methane and 1 Gg nitrous oxide for the year 1997, and in terms of CO_2 equivalent it is around 190 Tg. Methane emission is the dominant one, while nitrous oxide is negligible. Enteric fermentation is the major source of methane, accounting for 90% of total methane compared to 10% from manure management. Ruminants, especially bovines are the largest source (91%). The estimate also highlights hotspots, emission density, methane emissions from dairy and non-dairy bovines, milk yield vs methane, which are useful in formulating mitigation strategies. Top five states (Uttar Pradesh, Madhya Pradesh, Bihar, **Rajasthan** and Maharashtra) accounted for more than 50% of the country's emission (53%). The abatement option in the Indian context is also highlighted.

214. Swanson, D., S. Barg, S. Tyler, H. Venema, S. Tomar, S. Bhadwal, S. Nair, D. Roy and J. Drexhage (2010). **"Seven tools for creating adaptive policies."** Technological Forecasting and Social Change doi: 10.1016/j.techfore.2010.04.005.

Policies crafted to operate within a certain range of conditions are often faced with unexpected challenges outside of that range. Therefore, many policies have unintended impacts and do not accomplish their goals. Adaptive policies are designed to function more effectively in complex, dynamic, and uncertain conditions.

Based on over a dozen case studies on public policies relating to agriculture and water resources management in Canada and India, authors provide seven tools for policymakers that may be useful to create adaptive policies. Adaptive policies anticipate and plan for the array of conditions that lie ahead: (i) using integrated and forward-looking analysis; (ii) monitoring key performance indicators to trigger built-in policy adjustments; (iii) undertaking formal policy review and continuous learning; and (iv) using multi-stakeholder deliberation. But not all situations can be anticipated. Unknown unknowns and deep uncertainty will always be part of policymaking. Adaptive policies are able to navigate toward successful outcomes in settings that cannot be anticipated in advance. This can be done by working in concert with certain characteristics of complex adaptive systems and thereby facilitating autonomous actions among stakeholders on the ground. To a degree, adaptive policy tools 3 and 4 noted above can be used toward this purpose, but most directly, such autonomous tools include: (v) enabling self-organization and social networking; (vi) decentralizing decisionmaking to the lowest and most effective jurisdictional level; and (vii) promoting variation in policy responses. These seven tools can be useful as pragmatic guide for policymakers working in highly complex, dynamic, and uncertain settings.

215. TERI (2003). **Environmental threats, vulnerability and adaptation: case studies from India.** TERI Press-The Energy and Resources Institute, New Delhi, India.

This book is a compilation of working papers focusing on vulnerability and adaptation responses authored by researchers of The Energy and Resources Institute. It presents an overview of key environmental challenges that face developing countries, discusses it through case studies from India, and outlines existing adaptation approaches. Individual papers include: Environmental vulnerability: the climate change and sustainable development context; Poverty and vulnerability: linking environmental and socio-economic dimensions of adaptation; An approach to assessing vulnerability and coping strategies; GIS application in mapping vulnerability to multiple stressors for the agricultural sector in India; Impact of climate change on hydrology for better decision-making at a river basin level in India: a case study; Vulnerability to water-related stress: case studies in rural India; Mediating scarcity by design: water rights and legal pluralism in protective irrigation; Water scarcity and institutional adaptation: lessons from four case studies; Relative vulnerability of districts to a potential sea-level rise along the coastline of India; Impact of sea-level rise on salt-water intrusion in Goa; The rising seas: need for a longer-term perspective in coastal planning and adaptation for developing countries; Potential impact of climate change on forests; a

case study in Uttaranchal; Joint forest management in Haryana; interventions and socio-economic impacts; and Towards a new paradigm of poverty alleviation and vulnerability reduction.

216. Thamban, M., V. Purnachandra Rao, R. R. Schneider. (2002). "**Reconstruction of late Quaternary monsoon oscillations based on clay mineral proxies using sediment cores from the western margin of India**." Marine Geology **186**(3-4): 527-539.

In order to reconstruct the variations in the intensity of summer monsoon precipitation during the late Quaternary, two sediment cores from the southwestern continental margin of India were studied for their clay mineral composition and grain size parameters. Kaolinite, illite and gibbsite were dominant in a core off Cochin. Illite with increasing kaolinite content towards the core top was found to dominate in a core from the continental slope off Goa. Major sources of clays at both the core sites were from the hinterland rocks and soils. Careful evaluations of several factors that could complicate the clay distribution in marine environment indicate that the clay mineral parameters can be used as proxies for the intensity of summer monsoon precipitation in the past. The relatively low values of humidity proxies (kaolinite content, K/C and K/I ratios) and higher illite crystallinity with significant variations indicate that the summer monsoons in general were weaker during the late glaciation, with distinct events of intensification at ~28000 and 22000 yr BP. The last deglaciation was characterised by an increased terrigenous input with high values of humidity proxies during 15700-14800 cal yr BP, indicating an early strengthening of summer monsoon activity in the region. The most remarkable increase in kaolinite content, K/C and K/I ratios associated with much reduced values of chlorite and illite and illite crystallinity, however, occur between 8800 and 6400 cal yr BP. It appears that the Holocene precipitation maxima occurred after 9000 cal yr BP and lagged behind the precessional forcing. The late Holocene witnessed reduced rainfall activity and resultant decrease in hydrolysis starting at 5600 cal yr BP.

217. Thompson, L. G., T. Yao, E. Mosley-Thompson, M. E. Davis, K. A. Henderson, P. N. Lin. (2000). "**A high-resolution millennial record of the south Asian monsoon from Himalayan ice cores**." Science **289**: 1916-1919.

A high-resolution ice core record from Dasuopu, Tibet, reveals that this site is sensitive to fluctuations in the intensity of the South Asian Monsoon. Reductions in monsoonal intensity are recorded by dust and chloride concentrations. The deeper, older sections of the Dasuopu cores suggest many other periods of drought in this region, but none have been of greater intensity than the

greatest recorded drought, during 1790 to 1796 A.D. of the last millennium. The 20th-century increase in anthropogenic activity in India and Nepal, upwind from this site, is recorded by a doubling of chloride concentrations and a fourfold increase in dust. Like other ice cores from the Tibetan Plateau, Dasuopu suggests a large-scale, plateau-wide 20th-century warming trend that appears to be amplified at higher elevations.

218. Tompkins, E. L. and W. N. Adger (2004). **"Does adaptive management of natural resources enhance resilience to climate change?"** Ecology and Society **9**(2): 10. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art10.

Emerging insights from adaptive and community-based resource management suggest that building resilience into both human and ecological systems is an effective way to cope with environmental change characterized by future surprises or unknowable risks. Authors argue that these emerging insights have implications for policies and strategies for responding to climate change. Authors review perspectives on collective action for natural resource management to inform understanding of climate response capacity. Article demonstrates the importance of social learning, specifically in relation to the acceptance of strategies that build social and ecological resilience. Societies and communities dependent on natural resources need to enhance their capacity to adapt to the impacts of future climate change, particularly when such impacts could lie outside their experienced coping range. This argument is illustrated by an example of present-day collective action for community-based coastal management in Trinidad and Tobago. The case demonstrates that community-based management enhances adaptive capacity in two ways: by building networks that are important for coping with extreme events and by retaining the resilience of the underpinning resources and ecological systems… Although much adaptation to climate change is anticipatory, some also takes place in response to the impacts of single extreme events. Further, some climate change impacts, such as a significant and rapid rise in sea level, are likely to significantly alter the resource systems and their ecosystem services. The processes needed to adapt to catastrophic system changes would involve a major restructuring of the economy and society. Clearly, these are dangerous thresholds in the climate system that need to be avoided. There is, in effect, no substitute for the significant mitigation of emissions at the present time. Adaptation to both gradual and significant changes should involve encouraging the evolution of new institutions that are sensitive to the resilience of the ecosystems they are managing and

knowledgeable about the specific nature of the risks of climate change.

219. Tyagi, B. K. (2004). "**A review of the emergence of Plasmodium falciparum-dominated malaria in irrigated areas of the Thar Desert, India**." Acta Tropica **89**(2): 227-239.

Recently, there has been a resurgence of malaria in several parts of India, and the Thar Desert in north-western India, is currently suffering from the impact of repeated annual epidemics. Nearly all malaria epidemics in the Thar Desert have come about with the progression of canal-irrigation work, particularly the massive Indira Gandhi Nahar Pariyojana (IGNP). Therefore, the Thar Desert provides an excellent model for understanding the underlying factors responsible for the exacerbation of malaria, pathways of evolution of the epidemics, succession in anopheline fauna, changes in the vector breeding and feeding preferences and, most importantly, the possible repercussions of mismanagement of irrigation systems. Before the initiation of canalised irrigation only *Anopheles stephensi*, breeding exclusively in household and community-based underground water reservoirs, and transmitting malaria at a low level, was prevalent in the interior of the Thar Desert. Since the 1980s, extensive irrigation with water from three different canal systems has altered the desert physiography, vector preponderance, distribution and vectorial capacity, whilst triggering the emergence of *Plasmodium falciparum*-dominated malaria in the virgin levees of the Thar Desert. The major objective of bringing the Himalayan waters to the xeric environment of the Thar was to transform it into verdure through growing irrigation-intensive crops like paddy, groundnut, cotton, mustard, wheat and sugarcane, besides providing drinking water to the desert dwellers. The change in crop pattern, retention of high surface moisture, and excessive canalisation rife with mismanagement of irrigation water have attracted several anophelines, including *Anopheles culicifacies*, which were earlier unknown in the desert. Thus, *A. culicifacies* has penetrated into the interior of the Thar Desert, along with irrigation and is now established in vast areas covered by the IGNP project. The distribution of *P. falciparum*-dominated malaria in the Thar Desert is more or less synchronous with the spread of IGNP-related irrigated agriculture and of *A. culicifacies*.

220. Tyagi, B. K. and S. P. Yadav (1996). "**Malariological and sociological significance of 'tanka' and 'beri' in the Thar Desert, Western Rajasthan, India**." Journal of Arid Environments **33**(4): 497-501.

Both 'tanka' and 'beri', the well-like structures made for storing drinking water fetched from distant places or superficially

charged from the runoff water of the monsoon rains, are considered integral components of rural communities in the **Thar Desert** of **Rajasthan** State in north-western India. A. stephensi, the confirmed malaria vector in desert regions, breeds in these structures predominantly.

221. Tyagi, B. K. and S. P. Yadav (2001). "**Bionomics of malaria vectors in two physiographically different areas of the epidemic-prone Thar Desert, north-western Rajasthan (India)**." Journal of Arid Environments **47**(2): 161-172.

Entomological and parasitological investigations were carried out on malaria vectors and disease prevalence in two sets of villages, the highly irrigated Indira Gandhi Nahar Pariyojana (IGNP) command-area villages (Madassar and Awai), and the truly desertic non-command (unirrigated) area villages (Kanasar and Khetusar), located in different ecological conditions in the Thar Desert, north-western Rajasthan (India). Malaria prevalence, as determined through sustained fever surveys, was higher in the IGNP villages with a slide positivity rate (32%) marginally more than that of the unirrigated villages (25·5%), but with a high proportion of *Plasmodium falciparum* (76·6%) in the former villages as compared to the latter (16·6%). *Anopheles stephensi, A.culicifacies* and *A. subpictus* were amongst the eight anopheline species collected from all the four villages which were found positive for malarial parasites. *Anopheles stephensi* was the predominant species in the unirrigated villages (>95%), although in the irrigated villages *A. culicifacies* was also found. The major ecological changes associated with irrigation in the Thar Desert are understood to be playing an important role in accentuating the transmission of malaria by improving vector breeding conditions and survival in an otherwise hostile arid environment.

222. Upadhyay, R. C., S. V. Singh, A. Kumar, S. K. Gupta and A. Ashutosh (2007). "**Impact of Climate change on Milk production of Murrah buffaloes.**" Italian Journal of Animal Science **6**(2s): 1329-1332.

Global warming is likely to impact productivity of buffaloes due to their sensitivity to temperature changes. Air temperature, humidity, wind velocity and solar radiation are the main climate variables that affect buffalo production in tropical climate. In the present study sensitivity of lactating Murrah buffaloes to sudden temperature (Tmax, Tmin) change and THI have been analyzed from milk production and climatic records (1994-2004) of Karnal. Algorithms were developed and validated on lactating buffaloes during 2005-2006 at the Institute. A sudden change (rise or fall) in Maximum/Minimum temperature during summer and winter was

observed to affect milk production. The decline in minimum temperature (>3°C) during winter and increase (>4°C) during summer than normal were observed to negatively impact milk production upto 30% on the next or subsequent days after extreme event. The return to normal milk production depended on severity and time period of thermal stress/ event occurrence. The R^2 was very low for cool period observed during Feb- April/Sept-Nov and actual effect on milk production was minimum. This indicated that low THI had a relatively small effect on milk production performance. The lactation period of animals are shortened during extreme summer when THI were more than 80 and reproductive functions were also adversely affected. Thermal stressed buffaloes did not exhibit estrus or exhibited estrus for short period. The potential direct effects of possible climate change and global warming on summer season milk production of Murrah buffaloes were evaluated using widely known global circulation model UKMO to represent possible scenarios of future climate. Both milk production and reproductive functions of Murrah buffaloes are likely to be affected due to warming effects.

223. van Oosterom, E. J., F. R. Bidinger and E. R. Weltzien (2003). **"A yield architecture framework to explain adaptation of pearl millet to environmental stress."** Field Crops Research **80**(1): 33-56.

Functional knowledge of the physiological basis of crop adaptation to stress is a prerequisite for exploiting specific adaptation to stress environments in breeding programs. This paper presents an analysis of yield components for pearl millet, to explain the specific adaptation of local landraces to stress environments in **Rajasthan**, India. Six genotypes, ranging from high-tillering traditional landraces to low-tillering open-pollinated modern cultivars, were grown in 20 experiments, covering a range of non-stress and drought stress patterns. In each experiment, yield components (panicle number, grain number, 100 grain mass) were measured separately for main shoots, basal tillers, and nodal tillers. Under optimum conditions, landraces had a significantly lower grain yield than the cultivars, but no significant differences were observed at yield levels around 1 ton ha-1. This genotypexenvironment interaction for grain yield was due to a difference in yield strategy, where landraces aimed at minimising the risk of a crop failure under stress conditions, and modern cultivars aimed at maximising yield potential under optimum conditions. A key aspect of the adaptation of landraces was the small size of the main shoot panicle, as it minimised (1) the loss of productive tillers during stem elongation; (2) the delay in anthesis if mid-season drought occurs; and (3) the reduction in panicle productivity of the basal tillers under stress. In addition, a low investment in structural panicle weight, relative to vegetative crop

growth rate, promoted the production of nodal tillers, providing a mechanism to compensate for reduced basal tiller productivity if stress occurred around anthesis. A low maximum 100 grain mass also ensured individual grain mass was little affected by environmental conditions. The strategy of the high-tillering landraces carries a yield penalty under optimum conditions, but is expected to minimise the risk of a crop failure, particularly if mid-season drought stress occurs. The yield architecture of low-tillering varieties, by contrast, will be suited to end-of-season drought stress, provided anthesis is early. Application of the above adaptation mechanisms into a breeding program could enable the identification of plant types that match the prevalent stress patterns in the target environments.

224. Vogel, C., S. C. Moser, R. E. Kasperson and G. D. Dabelko (2007). "**Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships**." Global Environmental Change **17**(3-4): 349-364.

Vulnerability, adaptation and resilience are concepts that are finding increasing currency in several fields of research as well as in various policy and practitioner communities engaged in global environmental change science, climate change, sustainability science, disaster risk-reduction and famine interventions. As scientists and practitioners increasingly work together in this arena a number of questions are emerging: What is credible, salient and legitimate knowledge, how is this knowledge generated and how is it used in decision making? Drawing on important science in this field, and including a case study from southern Africa, we suggest an alternative mode of interaction to the usual one-way interaction between science and practice often used. In this alternative approach, different experts, risk-bearers, and local communities are involved and knowledge and practice is contested, co-produced and reflected upon. Despite some successes in the use and negotiation of such knowledge for `real' world issues, a number of problems persist that require further investigation including the difficulties of developing consensus on the methodologies used by a range of stakeholders usually across a wide region (as the case study of southern Africa shows, particularly in determining and identifying vulnerable groups, sectors, and systems); slow delivery of products that could enhance resilience to change that reflects not only a lack of data, and need for scientific credibility, but also the time-consuming process of coming to a negotiated understanding in science-practice interactions and, finally, the need to clarify the role of `external' agencies, stakeholders, and scientists at the outset of the dialogue process and subsequent interactions. Such factors, we argue, all hinder the use of vulnerability and resilience `knowledge' that is being generated and will require

much more detailed investigation by both producers and users of such knowledge.

225. Vom Brocke, K., E. Weltzien, A. Christinck, T. Presterl and H. H. Geiger (2003). **"Effects of farmers' seed management on performance and adaptation of pearl millet in Rajasthan, India."** Euphytica **130**(2): 267-280.

Pearl millet (*Pennisetum glaucum* [L.] R.Br.) is the staple food and fodder crop in western **Rajasthan.** This study quantifies the effects of three seed management strategies on environmental adaptation and trait performance. Results indicate that the plant characteristics employed by farmers in describing adaptive value and productivity is an effective approach in discriminating the type of millet adapted to stress and non-stress conditions. It was also found that introgression of modern varieties (MVs) leads to populations with a broader adaptation ability in comparison to pure landraces or MVs alone - but only if MV introgression is practised regularly and is combined with mass panicle selection. Under high-rainfall conditions, farmer grain stocks with MV introgression show similar productivity levels as modern varieties. Under lessening rainfall, pure landraces show, in tendency, higher grain yields. In conclusion, farmers' seed management could form an integral part of participatory breeding programs.

226. Vörösmarty, C. J., P. Green, J. Salisbury, R. B. Lammers. (2000). **"Global water resources: Vulnerability from climate change and population growth."** Science **289**(5477): 284-288.

The future adequacy of freshwater resources is difficult to assess, owing to a complex and rapidly changing geography of water supply and use. Numerical experiments combining climate model outputs, water budgets, and socioeconomic information along digitized river networks demonstrate that (i) a large proportion of the world's population is currently experiencing water stress and (ii) rising water demands greatly outweigh greenhouse warming in defining the state of global water systems to 2025. Consideration of direct human impacts on global water supply remains a poorly articulated but potentially important facet of the larger global change question.

227. Waite, T. A., L. G. Campbell, A. K. Chhangani and P. Robbins (2007). **"La Niña's signature: Synchronous decline of the mammal community in a 'protected' area in India."** Diversity and Distributions **13**(6): 752-760.

Mounting evidence indicates large-scale climatic phenomena such as El Niño Southern Oscillation (ENSO) can overwhelm

endogenous factors that govern the population dynamics of wild species. Authors add to this evidence by documenting an ENSO-related decline of large mammals in the Kumbhalgarh Wildlife Sanctuary, in Rajasthan, India. This event coincided with the drought of 2000, following two consecutive monsoon failures. Time series of biennial counts (1991-2005) shared a common feature: all 13 species declined in abundance from 1999 to 2001, with 11 species experiencing an apparent decline exceeding 25%. An ENSO index explained much of the variability in population size, apparently reflecting mass mortality and/or recruitment failure caused by the major 1998-2000 La Niña event, followed by a rapid rebound. ENSO apparently overwhelmed endogenous factors and synchronized the dynamics of the mammalian community. These findings may prove to be symptomatic of geographically broad impacts of large-scale climate on the dynamics of terrestrial vertebrate communities, even in protected areas. These findings reinforce the growing recognition that we should not overlook global-scale causal agents of ecological change.

228. Waite, T., A. Chhangani, L. Campbell, L. Rajpurohit and S. Mohnot (2007). **"Sanctuary in the city: Urban monkeys buffered against catastrophic die-off during ENSO-related drought."** EcoHealth **4**(3): 278-286.

Large-scale climatic drivers such as El Niño Southern Oscillation (ENSO) can overwhelm factors that ordinarily govern local population dynamics. We recently documented an ENSO-related die-off of mammals in the Kumbhalgarh Wildlife Sanctuary (KWS), Rajasthan, India. This die-off coincided with the La Niña-induced drought of 2000, which followed two consecutive monsoon failures. Hanuman langurs suffered a population crash of nearly 50% from 1999 to 2001. A Multivariate ENSO Index explained 80% of the variability in population size during the time series, and predicted the mass mortality and/or recruitment failure associated with the major La Niña event spanning 1999. Here, authors ask whether langurs in a large Rajasthani city, Jodhpur, were buffered against drought because humans provisioned them with food—for religious reasons. Unlike the KWS population, the Jodhpur population suffered no significant decline. In 2001, this urban population remained 95% as large as in 1999, before the drought. Variability in population size was also vastly reduced in Jodhpur. Thus, the impact of drought was dampened in a major urban area compared with an officially protected area. In this case, high human population density was not anathema for conservation. Wildlife sanctuaries in protected areas are undeniably important conservation tools, but these findings reinforce the notion that cities can serve as de facto sanctuaries for

some species. This study provides some hope for biodiversity conservation in a rapidly urbanizing world, particularly for holy and commensal species.

229. Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. "**Resilience, adaptability and transformability in social–ecological systems**." Ecology and Society **9**(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5.

Three related attributes of social–ecological systems (SESs) determine their future trajectories: resilience, adaptability, and transformability. Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Adaptability is the capacity of actors in the system to influence resilience (in a SES, essentially to manage it). Adaptability is the capacity of actors in a system to influence resilience. In a SES, this amounts to the capacity of humans to manage resilience. A characteristic feature of complex adaptive systems is self-organization without intent, and although the dynamics of SESs are dominated by individual human actors who do exhibit intent, the system as a whole does not (as in the case of a market). Nevertheless, because human actions dominate in SESs, adaptability of the system is mainly a function of the social component—the individuals and groups acting to manage the system. Their actions influence resilience, either intentionally or unintentionally. Their collective capacity to manage resilience, intentionally, determines whether they can successfully avoid crossing into an undesirable system regime, or succeed in crossing back into a desirable one. Transformability is the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable. The implications of this interpretation of SES dynamics for sustainability science include changing the focus from seeking optimal states and the determinants of maximum sustainable yield, to resilience analysis, adaptive resource management, and adaptive governance.

230. Wasson, R. J., G. I. Smith and D. P. Agrawal (1984). "**Late quaternary sediments, minerals, and inferred geochemical history of Didwana Lake, Thar Desert, India**." Palaeogeography, Palaeoclimatology, Palaeoecology **46**(4): 345-372.

Variations in clastic sediment texture, mineralogy of both evaporites formed at the surface and precipitates formed below the lake floor, and the relative chemical activities of the major dissolved components of the chemical precipitates, have allowed reconstruction of the history of salinity and water-level changes in Didwana Lake, **Thar Desert**, India. Hypersaline conditions prevailed at about the

Last Glacial Maximum, with little evidence of clastic sediments entering the lake. Between ca. 13,000 and 6000 B.P. the lake level fluctuated widely, the lake alternately hypersaline and fresh, and clastic sediments were delivered to the lake at a low rate. Deep-water conditions occurred ca. 6000 B.P. and clastic influx increased abruptly. The water level dropped towards 4000 B.P. when the lake dried briefly. Since 4000 B.P. the lake has been ephemeral with a lowered rate of sedimentation and mildly saline conditions rather like those of today. This sequence of changes documented in the lake parallels changes in vegetation recorded in published pollen diagrams from both the Thar and the Arabian Sea. Correlation of the various lines of evidence suggests that the climate of the Last Glacial Maximum at Didwana was dry and windy with a weak monsson circulation. The monsson was re-established between ca. 13,000 and a little before 6000 B.P., and, when winter rainfall increased ca. 6000 B.P., the lake filled to its maximum depth.

231. Yadav, R. K., K. Rupa Kumar and M. Rajeevan (2010). "**Climate change scenarios for Northwest India winter season**." Quaternary International **213**(1-2): 12-19.

A state-of-art regional climate modelling system, known as PRECIS (Providing REgional Climates for Impact Studies) and MRI-JMA (Meteorological Research Institute - Japan Meteorological Agency) AGCM (Atmospheric General Circulation Model) is applied to develop high-resolution climate change scenarios for Northwest (NW) India winter season. The present-day simulation (1961-1990) with PRECIS and (1990s) with MRI-JMA is evaluated. The models are able to resolve features on finer scales than those resolved by the GCM, particularly those related to improved resolution of the topography. The simulations under scenarios of increasing greenhouse gas concentrations and sulphate aerosols indicate marked increase in both precipitation and surface temperature towards the end of the 21st century.

232. Yadav, R. S., B. L. Yadav, B. R. Chhipa, S. K. Dhyani and M. Ram (2010). "**Soil biological properties under different tree based traditional agroforestry systems in a semi-arid region of Rajasthan, India.**" Agroforestry Systems, DOI: 10.1007/s10457-010-9277-z.

An investigation was carried out in an *Entisol* at farmers' field in Jaipur district, Rajasthan, India during 2002–2004 to evaluate the effect of traditionally grown trees on soil biological characteristics. Traditionally grown trees in farm lands for study consisted of *Prosopis cineraria* (L.), *Dalbergia sissoo* (Roxb.) ex DC, *Acacia leucophloea* (Roxb.) and *Acacia nilotica* (L.) Del. having a canopy diameter of 8 m. Results

revealed significant and substantial improvement in soil biological activity in terms of microbial biomass C, N and P, dehydrogenase and alkaline phosphatase activity under different tree based agroforestry systems as compared to a no tree control (cropping alone). Soil microbial biomass C, N and P under agroforestry varied between 262–320, 32.1–42.4 and 11.6–15.6 μg g^{-1} soil, respectively, with corresponding microbial biomass C, N and P of 186, 23.2 and 8.4 μg g^{-1} soil under a no tree control. Fluxes of C, N and P through microbial biomass were also significantly higher in *P. cineraria* based land use system followed by *D. sissoo*, *A. leucophloea* and *Acacia nilotica* in comparison to a no tree control. Thus, it is concluded that agroforestry system at farmers' field enhance soil biological activity and amongst trees, *P. cineraria* based system brought maximum and significant improvement in soil biological activity.

233. Yamin, F., Rahman, A., and Huq, S. (2005). "**Vulnerability, adaptation and climate disasters: a conceptual overview**." IDS Bulletin **36**(4): 1-14.

This paper is an introduction to a special issue focusing on the Linking Climate Adaptation (LCA) Project that aimed to ensure that poor people benefit from adaptation processes, rather than bearing greater burdens by, for example, having the risks caused by climate change shifted in their direction. The key research aim of the LCA Project was to determine what kind of procedural and institutional frameworks are needed to ensure that locally determined adaptation needs are linked "upwards" to national and international policy and institutional structures. This overview paper brings together policy relevant insights on this question while also explaining the conceptual underpinnings of the project, focusing on the nature of vulnerability and adaptation and policy processes to support community-led adaptation. The key conclusions are that climate change is a serious, ongoing threat to development and will add burdens to those who are already poor and vulnerable, and that climate vulnerability analysis should be incorporated systematically into the three main policy and institutional frameworks relevant for adaptation: development, disaster relief and climate change. Ways of fostering conceptual, operational and institutional linkages between these three domains are described, focusing on how these can help communities take centre stage in conducting vulnerability analysis and implementation to enhance their long-term capacities for adaptation.

234. Zickfeld, K., M. Eby, H. D. Matthews and A. J. Weaver (2009). "**Setting cumulative emissions targets to reduce the risk of dangerous climate change.**" Proceedings of the National Academy of Sciences **106**(38): 16129-16134.

Avoiding "dangerous anthropogenic interference with the climate system" requires stabilization of atmospheric greenhouse gas concentrations and substantial reductions in anthropogenic emissions. Here, we present an inverse approach to coupled climate-carbon cycle modeling, which allows us to estimate the probability that any given level of carbon dioxide (CO_2) emissions will exceed specified long-term global mean temperature targets for "dangerous anthropogenic interference," taking into consideration uncertainties in climate sensitivity and the carbon cycle response to climate change. Authors show that to stabilize global mean temperature increase at 2°C above preindustrial levels with a probability of at least 0.66, cumulative CO_2 emissions from 2000 to 2500 must not exceed a median estimate of 590 petagrams of carbon (PgC) (range, 200 to 950 PgC). If the 2°C temperature stabilization target is to be met with a probability of at least 0.9, median total allowable CO_2 emissions are 170 PgC (range, −220 to 700 PgC). Furthermore, these estimates of cumulative CO_2 emissions, compatible with a specified temperature stabilization target, are independent of the path taken to stabilization. This analysis therefore supports an international policy framework aimed at avoiding dangerous anthropogenic interference formulated on the basis of total allowable greenhouse gas emissions.

Endnotes

[1] Gleick, P. H. et al., Climate change and the integrity of science, *Science*, **328**, 689-690, 2010.

[2] O'Brien, K., R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, J. West., Mapping vulnerability to multiple stressors: climate change and globalization in India, *Global Environmental Change Part A* **14**, 303-313, 2004.

[3] Mall, R. K., A. Gupta, R. Singh, R. S. Singh and L. S. Rathore, Water resources and climate change: An Indian perspective, *Current Science,* **90**, 1610-1626, 2006.

[4] Kumar, K. R., A. K. Sahai, K. K. Kumar, S. K. Patwardhan, P. K. Mishra, J. V. Revadekar, K. Kamala and G. B. Pant, High-resolution climate change scenarios for India for the 21st century, *Current Science,* **90**, 334 – 345, 2006.

[5] Goyal, R. K., Sensitivity of evapotranspiration to global warming: a case study of arid zone of Rajasthan (India), *Agricultural Water Management,* **69**, 1-11, 2004.

[6] Singh, R. S., P. Narain and Sharma, K. D., Climate changes in Luni river basin of arid western Rajasthan (India)', *Vayu Mandal*, **31**, 103–106, 2001.

[7] R. K. Mall, R. Singh, A. Gupta, G. Srinivasan, L. S. Rathore, Impact of climate change on Indian agriculture: a review (erratum), *Climatic Change*, **82**, 225–231, 2007.

[8] Ajai, A. S. Arya, P. S. Dhinwa, S. K. Pathan and K. G. Raj, Desertification/land degradation status mapping of India, *Current Science*, **97**, 1478-1483, 2009.

[9] Goswami, P. and K. V. Ramesh, The expanding Indian desert: Assessment through weighted epochal trend ensemble, *Current Science*, **94**, 476-480, 2008.

[10] Kar, A., Wind erosion potentials in the Thar-Megathar region from AD 1951 to 2100: Patterns and implications, Abstract in International conference on Nurturing Arid Zones for People and The Environment: Issues and Agenda For The 21st Century, November 24-28, 2009, CAZRI, Jodhpur, Rajasthan, India, pp. 24-25.

[11] Pandey, D. N., A. K. Gupta, D. M. Anderson, Rainwater harvesting as an adaptation to climate change, *Current Science*, **85**, 46-59, 2003.

[12] Gupta, A. K., Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration, *Current Science*, **87**, 54-59, 2004.

[13] Gupta, A.K., D.M. Anderson, D.N. Pandey, A.K. Singhvi, Adaptation and human migration, and evidence of agriculture coincident with changes in the Indian summer monsoon during the Holocene, *Current Science*, **90**, 1082-1090, 2006.

[14] Allchin, B. and Allchin, R., *The Rise of Civilization in India and Pakistan*, Cambridge Univ. Press, London, 1982.

[15] Allchin, R. and Allchin, B., *Origins of a Civilization*, Viking-Penguin India, New Delhi, 1997.

[16] Enzel, Y., L. L. Ely, S. Mishra, R. Ramesh, R. Amit, B. Lazar, S. N. Rajaguru, V. R. Baker, A. Sandler, High-resolution Holocene environmental changes in the Thar desert, northwestern India, *Science*, **284**, 125-128, 1999.

[17] Staubwasser, M., Sirocko, F., Grootes, P. M. and Segl, M., Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability, *Geophys. Res. Lett.*, 3002, **30**, 1425, doi:10.1029/2002GL016822, 2003.

[18] Swanson, D., S. Barg, S. Tyler, H. Venema, S. Tomar, S. Bhadwal, S. Nair, D. Roy and J. Drexhage, Seven tools for creating adaptive policies, *Technological Forecasting and Social Change*, doi: 10.1016/j.techfore.2010.04.005, 2010. See also, Darren A. Swanson and Suruchi Bhadwal (Editor), *Creating Adaptive Policies: A Guide for Policy-making in an Uncertain World*, Sage, IISD/IDRC/Sage, 2009, available at http://www.idrc.ca/openebooks/467-3/

[19] Pandey, D. N., Equity in climate change treaty, *Current Science*, **86**, 272-281, 2004.

[20] Narain, P., M. A. Khan and G. Singh, Potential for Water Conservation and Harvesting against Drought in Rajasthan, India, Working Paper 104/Drought Series: Paper 7, International Water Management Institute, Colombo, Sri Lanka, 2005.

[21] Khanna, R. K., R. S. Rathore and C. Sharma, Solar still an appropriate technology for potable water need of remote villages of desert state of India, Rajasthan, *Desalination*, **220**, 645-653, 2008.

[22] Sharma, K. D., Groundwater management for food security, *Current Science*, **96**, 1444-1447, 2009.

[23] Rodell, M., I. Velicogna and J. S. Famiglietti, Satellite-based estimates of groundwater depletion in India, *Nature*, **460**, 999-1002, 2009.

[24] Akermann, K., L. Herberg and A. Kalisch, How do small farmers respond to climate change in Rajasthan? *Rural 21*, **4**, 30-32, 2009.

[25] Kaul, M., V. K. Dadhwal and G. M. J. Mohren, Land use change and net C flux in Indian forests, *Forest Ecology and Management*, **258**, 100-108, 2009.

[26] Pandey, D. N., Global climate change and carbon management in multifunctional forests, C*urrent Science*, **83,** 593-602, 2002.

[27] Pandey, D. N., Carbon sequestration in agroforestry systems, *Climate Policy*, **2**, 367-377, 2002.

[28] Pandey, D. N., Multifunctional agroforestry systems in India, *Current Science*, **92**, 455-463, 2007.

[29] Singh, V.P., NREGA and agroforestry for addressing the challenges of climate change, Presentation, ICRAF, South Asia office, New Delhi, 2010.

[30] Goswami, P. and K. V. Ramesh, The expanding Indian desert: Assessment through weighted epochal trend ensemble, *Current Science*, **94**, 476-480, 2008.

[31] Thomas, D. S. G., M. Knight and G. F. S. Wiggs, Remobilization of southern African desert dune systems by twenty-first century global warming, *Nature*, **435,** 1218-1221, 2005.

[32] Singh, G. and T. R. Rathod, Plant growth, biomass production and soil water dynamics in a shifting dune of Indian desert, *Forest Ecology and Management*, **171**, 309-320, 2002.

[33] Singh, S. K., A. K. Singh, B. K. Sharma and J. C. Tarafdar, Carbon stock and organic carbon dynamics in soils of Rajasthan, India, *Journal of Arid Environments*, **68**, 408-421, 2007.

[34] Pandey, D. N., Sequential Restoration for Enhancement of Biodiversity and Productivity in Thar Desert, In, UNESCO-MAB International Workshop on Ensuring the Future of Drylands: Towards Implementing the MAB Agenda for a Sustainable Future of Drylands, 11-15 November, 2007, AFRI/CAZRI, Jodhpur, India.

[35] Khanna, R. K., R. S. Rathore and C. Sharma, Solar still an appropriate technology for potable water need of remote villages of desert state of India, Rajasthan, *Desalination*, **220**, 645-653, 2008.

[36] Purohit, I. and P. Purohit, Techno-economic evaluation of concentrating solar power generation in India, *Energy Policy* **38**, 3015-3029, 2010.

[37] Singh, H., A. K. Singh, P. B. L. Chaurasia and A. Singh, Solar energy utilization: A key to employment generation in the Indian Thar Desert, *International Journal of Sustainable Energy* **24,** 129-142, 2005.

[38] Panwar, N. L. and N. S. Rathore, Potential of surplus biomass gasifier based power generation: A case study of an Indian state Rajasthan, *Mitigation and Adaptation Strategies for Global Change* **14**, 711-720, 2009

[39] Jetz, W., Wilcove, D.S., Dobson. A.P., Projected Impacts of Climate and Land-Use Change on the Global Diversity of Birds, *PLoS Biol*ogy **5**, e157. doi:10.1371/journal.pbio.0050157, 2007.

[40] Prugh, L. R., K. E. Hodges, A. R. E. Sinclair and J. S. Brashares, Effect of habitat area and isolation on fragmented animal populations, *Proceedings of the National Academy of Sciences*, **105**, 20770-20775, 2008.

[41] Revi, A., Climate change risk: An adaptation and mitigation agenda for Indian cities, *Environment and Urbanization*, **20**, 207-229, 2008.

[42] Singh, V. S., D. N. Pandey and P. Chaudhry, *Urban Forests and Open Green Spaces: Lessons for Jaipur, Rajasthan, India*, RSPCB Occasional Paper No. 1/2010, Rajasthan State Pollution Control Board, Jaipur, Rajasthan, India, pp. 23.

[43] Pandey, D. N., A. C. Chaubey, A. K. Gupta and H. Vardhan, Mine spoil restoration: A strategy combining rainwater harvesting and adaptation to random recurrence of droughts in Rajasthan, *International Forestry Review*, **7**, 241-249, 2005.

[44] Pandey, D. N., Sustainability science for mine-spoil restoration, *Current Science*, **83**, 792-793, 2002.

[45] Jaglan, M. S. and M. H. Qureshi, Irrigation development and its environmental consequences in arid regions of India, *Environmental Management*, **20**, 323-336, 1996.

[46] Chauhan, S. S., Desertification control and management of land degradation in the Thar desert of India, *The Environmentalist*, **23**, 219-227, 2003.

[47] Gajja, B. L., P. Rajendra, R. S. Mertia, K. Chand and J. S. Samra, Impact of shelterbelts on net returns from agricultural production in arid Western Rajasthan, *Agricultural Economics Research Review*, **21**, 118-122, 2008.

[48] Goswami, P. and K. V. Ramesh, The expanding Indian desert: Assessment through weighted epochal trend ensemble, *Current Science*, **94**, 476-480, 2008.

[49] Green Wall of China, http://en.wikipedia.org/wiki/Green_Wall_of_China

[50] Wang, X., Z. Dong, J. Zhang and L. Liu, Modern dust storms in China: an overview, *Journal of Arid Environments*, **58**, 559-574, 2004.

[51] Parungo, F., Z. Li, X. Li, D. Yang and J. Harris, Gobi dust storms and The Great Green Wall, *Geophys. Res. Lett.*, **21**, 999-1002, 1994.

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