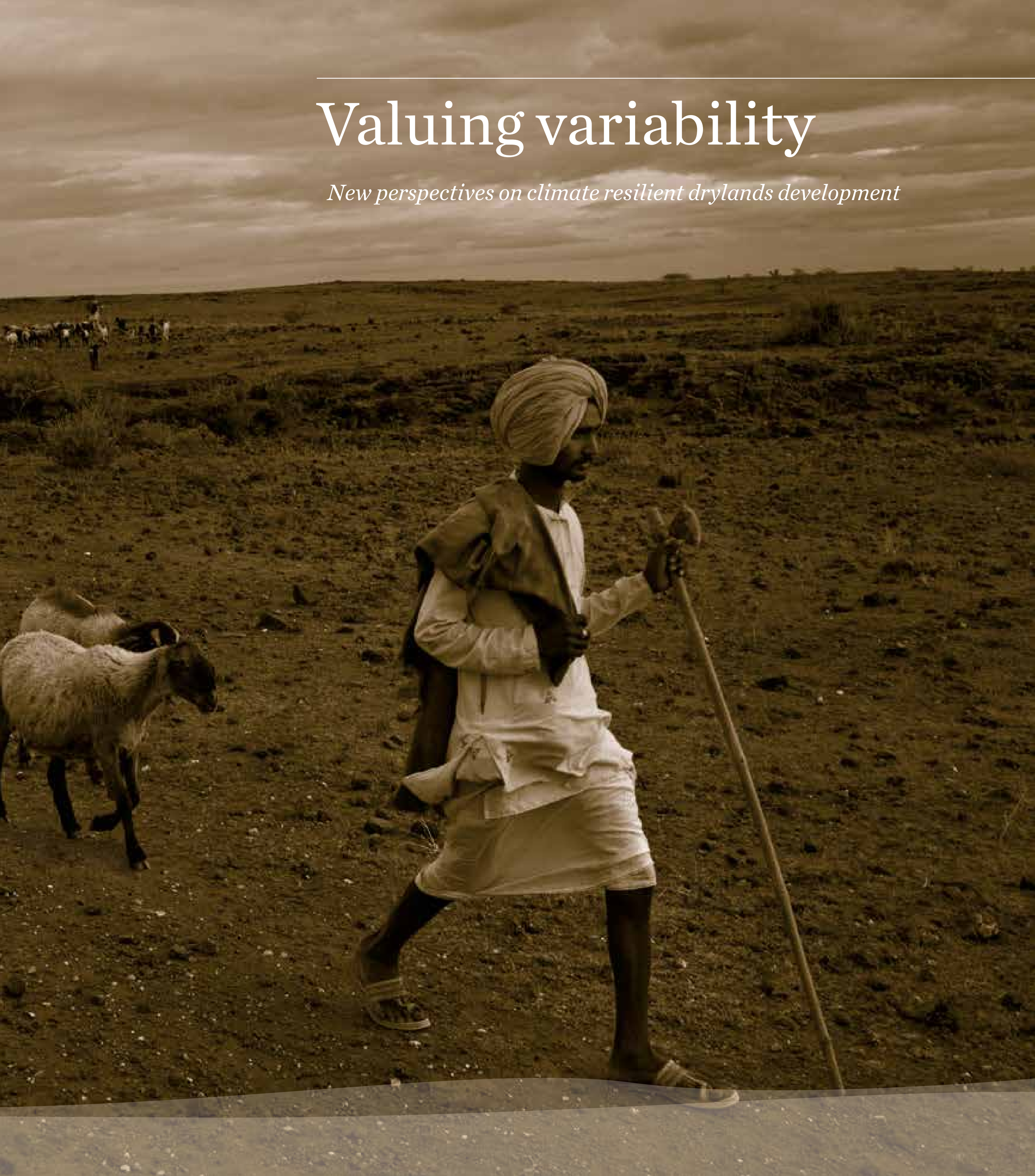
Valuing variability

New perspectives on climate resilient drylands development



Valuing variability

New perspectives on climate resilient drylands development

Preface

Drylands are a big part of our global heritage, in terms of the crops and livestock we've drawn from them, and the practices we've learnt from coping with water-short livelihood systems. From the fertile crescent in Mesopotamia, to the wide open grazing lands of East and West Africa, we've been fortunate in the ingenuity of local people's ability to design responses to variability. We can all learn from their experience. Over the next three decades, climate change, and the increasing uncertainty it brings, demand a focus on policies which make sense for dryland peoples. Agricultural economies in dryland areas are widely viewed as being in crisis, suffering from persistent food insecurity due to a lack of rainfall. Many governments look for solutions that will replace existing livelihoods, seeking to master nature by choosing interventions to 'stabilise' the environment by creating a green oasis. But history shows that this rarely succeeds in the long term, and commonly leads to many other problems. Mastery needs to give way to accepting and living with uncertainty.

In reality, many dryland people know how to live with climate change and work with fluctuating rainfall. They recognise variability as an inherent feature of their landscapes, and they use it opportunistically to generate the foods we all eat. By understanding more about climatic variability, we can help dryland economies reach their true potential. As policy makers and shapers of broader debate, we need to recognise the huge value of local knowledge and the customary wisdom of people who live there. We must build on the sound scientific information we now have on the drylands, and support agricultural development and investment which works with the grain of climate change, rather than trying to work against it.

Camilla Toulmin

Director, International Institute for Environment and Development

IIED, with funding from the Ford Foundation, and in partnership with University of Peking in China, the Revitalizing Rainfed Agriculture Network and Rainfed Livestock Network in India, and the Drylands Learning and Capacity Building Initiative in Kenya are managing a programme entitled *New perspectives on climate resilient drylands development (2012-15)*. Research on the assumptions, arguments and evidence that underpin national and global narratives on the drylands has been used to formulate more progressive perspectives based on scientific evidence and traditional local knowledge and experience, and which are published in this book.

Read more at:
www.iied.org/advocating-for-policies-laws-support-adaptive-management

Acknowledgements

Lead author

Saverio Krätli

Editor

Helen de Jode

Published in 2015 by the International Institute for Environment and Development (IIED).

ISBN 978-1-78431-157-5

Citation

Krätli, S. (2015)
Valuing variability:
New Perspectives on climate resilient drylands development.
IIED. Edited by de Jode, H.

Available from:

http://pubs.iied.org/10128IIED.html

Design

platform1design.com

FORD FOUNDATION

The views in this publication do not necessarily reflect those of the Ford Foundation.

This book would not have been published without funding from the Ford Foundation. Our deepest thanks go to Margaret Rugadya, Natural Assets Programme Officer, for her patience and support. Nor would it have been written without the dedication of the following individuals who contributed case study material, testimonies and some beautiful photos from field research they carried out specifically for this book.

From China, we are grateful to Yanbo Li, Wenjun Li and Gongbuzeren of Peking University for their work investigating new governance systems for managing the rangelands in Inner Mongolia in the wake of the rangeland contract policy and grazing ban. We also thank Huilan Wei, Songsong Zhao, Binru Yang and Seth Cook, respectively from Lanzhou University and the International Institute for Environment and Development, as well as photographer Jianping Han for their research that documents traditional Chinese dryland farming and rainwater harvesting techniques.

From India, we acknowledge Nitya Sambamurti Ghotge and Dileep Halse of Anthra and members of the Rainfed Livestock Network for their work capturing the integration strategies of Maldhari pastoralists in Maharashtra State, western India; Kamal Kishore of the Rainfed Livestock Network for his sound advice in framing some of the arguments; Ilse Koehler-Rollefson of the League for Pastoral Peoples and Endogenous Livestock Development, and Hanwant Singh Rathore, Dailibai Raika, and Jagdish Paliwal from Lokhit Pashu-Palak Sansthan for detailing the profits Raika shepherds from Rajasthan make from their annual migrations; Athar Parvaiz, a free-lance journalist and researcher, for his research articles and photos on the Banni buffalo and Kharai and Kachchhi camels from Kachchh District in Gujarat State, and to Sabyasachi Das and Ramesh Bhatti of Sahjeevan for their support; and, Rajeswari Sarala Raina, Mocherla Venkata Ramachandrudu, Sakkhari Kiran and Sneha Ananthakrishnan, members of the Revitalizing Rain-fed Agriculture Network for their research demonstrating farmers capacities for agronomic and management innovation, given explosive diversity and variability in India's drylands.

From Kenya, we thank Greg Akall and Sean Avery for their studies on irrigation in Turkana County and the impacts of the Gibe III dam in Ethiopia on Omo-Gibe River system and Lake Turkana in Kenya; Laban Peter Ayiro for his paper on the limitation of the formal education system in societies attuned to managing variability; and, Jarso Mokku, Halkano Boru, Vanessa Tilstone and Dorina Prech from the Drylands Learning and Capacity Building Initiative for their very able management of the research process and subsequent printing of the book in Kenya.

Many other people from Africa, Asia and Europe have contributed to the book by providing information on their or others' existing research, short testimonies, advice on where to find additional information and key insights on how to frame a more positive and faithful perspective of the drylands in which many of them live and work. We cannot acknowledge everyone's input for lack of space, but those whose material we used are credited on the relevant pages.

Our thanks to Alan Hesse for his wonderful cartoon of the difficulties faced by 'Formula 1' cows in arid environments, Emilia Roza Sulek for her fascinating selection of lesser-known facts on the drylands, to Morgan Williams and Greg Wells for their tight management of the finances, the IIED Communications Team for their professional support and flexibility, and for all those who willingly gave us permission to use their stunning photos at no cost – they are individually credited on the last page of the book.

Finally, we are deeply appreciative of the dedication of Saverio Krätli, Lead Author and Helen de Jode, Editor in producing this book, crafting from the case studies and a mass of other material, a different, more positive and ultimately more progressive and exact perspective of the drylands.

Ced Hesse

Principal Researcher, IIED

April 2015

Contents

Vibrant dryland economies in China, India and East Africa.

About this book

'A book is like a garden carried in the pocket'

Chinese proverb

This book is a challenge to those who see the drylands as naturally vulnerable to food insecurity and poverty. It argues that improving agricultural productivity in dryland environments is possible by working with climatic uncertainty rather than seeking to control it – a view that runs contrary to decades of development practice in arid and semi-arid lands. Across China, Kenya and India – and most other dryland countries – family farmers and herders relate to the inherent variability of the drylands as a resource to be valued, rather than a problem to be avoided. By exploring these vibrant agricultural economies that take advantage of variability, this book inverts long-standing negative views about food security in the drylands.

The drylands cover 40% of the world's landmass, and are seen by many to be the areas at greatest risk from climate change due to their low, variable and unpredictable rainfall patterns. Their food production systems are perceived to be inefficient, and agricultural development in the drylands has become a pressing challenge for policy makers focused on food security and resilience. Most large-scale agricultural development strategies operate on the assumption that introducing uniformity and stability in the environment is the pathway to securing a harvest and increasing productivity. This pathway may include levelling landscapes, adding chemical fertilisers, introducing irrigation or planting high-yielding (and highly uniform) crop varieties. Wanting to control environmental variability seems both logical and attractive, but in contexts where variability is structural, control is not only very costly but is usually unsustainable and accompanied by high negative externalities.

There is an alternative pathway to securing agricultural productivity and food security in the drylands that manages variability rather than trying to eliminate it. At the heart of scientific research in dryland environments over the last thirty years is an understanding that variability in the drylands is structural – there is no state of stability to return to: average rainfall is meaningless, prediction is impossible, and a good rainy season and a drought may be only a couple of hours walk apart. Farmers and herders engage with this structural variability, making real-time adjustments in cropping and grazing strategies, with those who take on the risks often being the most productive. Other sectors routinely incorporate risk (air traffic control, the stock market, the military) but agricultural development has instead sought to control the drylands and 'keep things still'. The results have frequently been disastrous.

Agricultural investments that seek to control the environment fail to unlock the full capacity of the drylands and frequently undermine local economies and livelihoods – creating inequity, degradation and conflict. This book shows how, when pursuing resilient development in the drylands, it is better to forbear the search for control and 'best' solutions. Strategies should involve integration and flexibility, and focus on relationships between people and the environment. In reading this book, motivated policy makers and development agents are urged to overhaul their present thinking about 'controlling' drylands and consider the possibility of an alternative pathway, one based on taking advantage of variability. Having done so, the inherent productivity of the drylands will become more recognisable and the challenges of food security and resilience in a world increasingly dominated by variability will appear less daunting.

The world's drylands

- Drylands are not on the margins of the 'economically productive' world: they are vast areas often right in the centre, such as the Great Plains of North America and the wheat regions of Ukraine and Kazakhstan. Los Angeles, Mexico City, Delhi, Cairo and Beijing are all situated in drylands.
- Two and a half billion people (including 40% of Africans, 39% of Asians and 30% of South Americans) live in drylands.[1]
- Dryland ecosystems are extremely diverse. They include the Mediterranean systems, the cold deserts of Mongolia and Chile, the Sahara and Sahel of Africa, and the high altitude drylands of Iran and Afghanistan. The Arctic Circle ecosystems are also classified as drylands.[2]
- Though drylands are perceived as particularly sensitive to environmental degradation, research shows that they do not feature strongly in on going land degradation: 78% of degradation by area is in humid regions whereas 22% is in drylands.[3]
- Drylands have given the world its most important staple foods. Maize, beans, tomato and potatoes originate from the drylands of Mexico, Peru, Bolivia and Chile. Millet and sorghum, and various species of wheat and rice come from the African drylands.[4]
- Where dryland ecosystems support woody vegetation, trees and tree products contribute to national economies (eg 80% of rural energy in Mexico; 70% in Peru and north-east Brazil; 70% of national energy in the Sudan; and 74% of total energy consumption in Kenya).[5] Some 18% of dryland areas is occupied by forest and woodland systems.[6]

- Drylands in Europe and North America generate an estimated US$4,290 and US$277 in economic value respectively, per hectare per year; but this figure jumps to US$6,462 in Asia, US$9,184 in Africa and US$9,764 in Latin America.[7]
- In India, 45% of agricultural production takes place in the country's dryland areas.[8]
- Drylands are home to the world's largest diversity of mammals, for example in the Serengeti in East Africa. Plant species endemic to drylands make up 30% of the plants under cultivation today.[9]
- According to the Living Planet Index, the global decline in (wild) species is much more marked in tropical species populations. The percentages of livestock breeds reported at risk and extinct in drylands have – with the exception of Africa – been below the global levels.[10]
- Drylands provide 44% of the world's cultivated systems, 50% of the world's livestock, and contain a variety of important habitats for vegetable species, fruit trees and micro-organisms.[11]
- In Argentina, 50% of agricultural production and 47% of livestock production occurs on drylands, which are home to 30% of the country's 40 million people.[12]
- Animal products from dryland grazing systems have a smaller water footprint than those from industrial systems.[13]
- Research shows that the average yield in drylands could be increased by 30% to 60% by making available an additional 25 to 35mm of water to crops corresponding to 5–8% of expected precipitation during critical growth periods through water conservation and harvesting. These benefits are attainable in most dryland areas of the world.[14]
- About 72% of drylands occur in developing countries and this proportion increases with aridity: almost 100% of all hyper-arid lands are in the developing world.[15]

It is a nice sunny morning. You are driving into work, air-conditioning on and listening to your favourite radio station. Life is great. Suddenly, there is a frightening bang. At seventy miles an hour, your car shakes and skids out of control. Certainty shatters. There is no time to think. Depending on what you do in the next few seconds, you might end up joking about the incident with your colleagues over lunch, or you might never see them again. Before you know it, your foot is flying to the brake, your hands want to clutch at the wheel and turn it to safety. Every muscle in your body is focused on the need to feel in control.

As drivers learn when preparing for their licence, if you do follow the temptation to feel in control when a tyre bursts – pushing down on the brake and turning the wheel to pull off the road – chances are that you will not survive to tell the story. What driving instructors recommend is something quite counterintuitive: pushing on the accelerator (avoiding the brake) and letting the wheel move freely, steering only very gently if necessary. Although it seems illogical, during a tyre blowout control is regained by doing something that feels like giving it away. Forcing control upon these circumstances is likely to result in the opposite of safety: an increase in danger.[16]

Q. Accelerate and let go of the wheel when I have lost control at seventy miles an hour?

A. Yes. Accelerating increases the grip on the road, left by itself the vehicle should take a straight course.

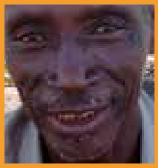
Driving has its hazards, but is still a relatively stable and predictable situation where, once back in control of the wheel, one can reasonably expect to remain so. There are other contexts however in which unexpected contingencies are the norm: contexts where variability and unpredictability always dominate; where dynamic correlations of forces inextricably entangle causes and effects, making control effectively impossible. In these contexts, the best course of action is to manage the state of being without control; that is, managing the variability rather than trying to eliminate it.

For decision makers faced with these contexts, resisting the temptation to force control upon the circumstances can be just as difficult as keeping the foot off the brake when one of your tyres blows out. This book is about these difficulties, but also about the opportunities of refraining from this temptation, with regard to one of the largest domains of structural variability: the global drylands.

Part 1

Variability in dryland environments

"I've been keeping a log of the rainfall since 1988. Some people say the rain is decreasing but it's more complicated. Some years a lot of rain comes and the harvest is bad, some years it's dry but we do well. It's the way the rain comes (sanji na cogo) that matters the most. If we get a big rain at the start of the season, we'll go out and sow. Another big rains a week or so later is good, but if it rains night and day, the millet can't grow properly, there's not enough heat in the soil."



Makono Dembele
59, Farmer Dlonguebougou, Mali.

A ram on migration stops for a nibble in the Chuksa mountains, Navajo

It takes about five minutes for a pot of tea to boil on a small fire. One hundred times more heat, if evenly spread out over a year, would not even make the pot warm. The overall quantity of heat is important but what is really critical, when you are making tea, is to have enough of it concentrated under your pot. In other words, what matters is distribution. It is exactly the same with rainfall in the drylands.

Drylands are seen as being areas that lack sufficient rainfall for plant growth, but it does rain in the drylands – at times even too much. Crucially, it rains in concentrated bursts and in unpredictable patterns over time and space. When this unpredictability combines with different soils types and varying topography there is even greater variability, creating concentrated micro-niches of moisture that support plant growth. The temporal and seasonal variability of the rainfall means that dryland plants – even of the same species – will begin and end their life cycles at different times; a feature which becomes crucially important for herders who are seeking access to the most nutritious green pasture for as long as possible. For dryland farmers this variability creates other opportunities – including less concentrated demand for weeding and improved crop storage.

It is only relatively recently that the variability in the drylands has been acknowledged and understood. For a long period agricultural development has sought ways to control the drylands environment, but with little success. This book explains an alternative view of the drylands and focuses on the opportunities offered by its variability, and the advantages of understanding the productivity that results from engaging with variability in a positive way. This opportunity is critical in our attempts to cope with a changing climate.

“Whenever we deal with pastoralists, the seasonal climate information and its forecasts are as crucial to them as the daily forecasts. They ask, ‘Are we likely to get good rains next season?’ To them good rains are not what other sectors of the economy refer to. For the pastoralists it is about whether there will be enough pasture and water to take them through the next dry season. They ask ‘How is the distribution of the rain? Can it sustain pastoral activities?’ Poor rains are when its distribution is bad. The rain comes all at once and stops. Good distribution results in a lot of pasture from even few days rain. Good rain means enough water, and well spread, and well paced, pasture that is available until the next rainy season.”

Ayub Shaka
Assistant Director of the Public Weather Services and Media
Kenya Meteorological Services Department

'A favourable pattern of precipitation during the growing period can result in good yields even when the annual total is much below average. In contrast, there is no assurance of good production in years even when precipitation is greater than average if it occurs at times when crop water requirements are low.'[17]

‘There is a general conception (perhaps as a result of continuous restatement in official reports) that the rainy season ‘normally’ begins in late March or early April; that the rains then continue with reasonable regularity until late September or early October, when the dry season begins; and that the dry season is punctuated by occasional showers […] This ‘normal’ pattern is, however, exceptional rather than typical […] The amount and incidence of rainfall over the area varies considerably [...] average figures, either for the entire area or for single stations, are very misleading.’[18]

The definition of drylands and introducing variability

The concept of 'drylands' is relatively new, introduced in the context of the debate on desertification. The conventional definition from the United Nations Convention to Combat Desertification (UNCCD) uses a scale of aridity calculated on the basis of the ratio between rainfall and potential evaporation. More precisely, between mean annual precipitation and potential evaporation from soil, plus transpiration from vegetation, based on the assumption of a large area uniformly covered with short green vegetation and uniformly supplied with rainfall.[19] Under the UNCCD definition, the drylands include a range of environments, from cultivated lands to savannahs and deserts, with a lack of water limiting vegetation growth as their defining factor. It is common practice to split these drylands into four bands or categories: hyper-arid (or 'true desert'), arid, semi-arid and, dry sub-humid.

The abstract UNCCD definition does a good job in highlighting aridity at a regional and global scale, but it is at the cost of ignoring everything else. In particular, it does not capture seasonal variations, which are crucially important for determining whether an area is suitable for agricultural development. The annual rainfall of a given area may be a limiting factor to vegetation growth if it is uniformly distributed; but like the small fire that boils the tea (page 15), it can be perfectly sufficient to support plant growth if its distribution follows certain patterns of concentration.

FAO have introduced an alternative definition of drylands that is based on the length of the period in the year when rainfall is sufficient for the growth of crops or vegetation (known for short as 'length of growing period', or LGP).[20] This more practically oriented definition opens up a window to include variability as, in principle, 'length of growing period' can also capture the fact that the growth of crops and pasture is not exclusively ruled by climate/rainfall, but is also the outcome of a relationship between agricultural producers and the environment. In practice however, length of growing period is understood as an objective condition, expected to determine the producers' options (eg crop choices or farming and management strategies) but not affected by them.[21]

The reality is that, in the drylands, the rainy season can quite literally miss you by a few hundred metres. Average figures from widely scattered rainfall stations contribute to an impression of uniformity that hides sharp spatial variability on the ground – variability that is crucial to farmers and herders. Behind the abstract stability of average precipitation, the drylands include a constellation of hugely different rainfall patterns that are both 'good' and 'bad'. An annual average 400mm rainfall may mean not a drop in some places and 600-800mm in others. In the drylands the 'length of growing period' therefore turns out to be a large and flexible bandwidth, rather than a rigid threshold.

The view of the drylands taken in this book focuses on the opportunities in this variability; a view that realises temporal and spatial rainfall distribution is more important than rainfall averages, and that the relationship between producers and their environment is crucial.

In the drylands, rainfall variability is important for ensuring moisture retention in soil. For example, one small first rain of 5mm followed by one of 20mm the next day is likely to be more useful than a rainy season opening with 50mm rainfall all at once, which will be washed away on the dry soil.

"On 'glacis' soils [hardpans with shallow soils of sand and clay], two small rains are much better as they infiltrate and moisten the soil, which allows better germination of the seeds. A big rain carries off all the sand , and if it comes after sowing when the plants are just seedlings they can be carried into the river."

Biba Issaka

from Koria Gourma village, southern Niger.

Variability, diversity and real-time management

The amount of rain in the drylands is actually one element (if a particularly important one) of a much bigger complex of variables. The technical parameter 'potential evapo-transpiration' (PET), used for measuring aridity and classifying ecological zones, assumes uniformity in soil, vegetation cover and distribution of moisture; however, not only is rainfall not the least bit uniformly distributed, but variety in soils, topography and vegetation in the drylands creates great diversity in the way the moisture is then absorbed and retained.

Sandy dunes have a bad press as symbols of desertification, but in fact they are the first soil to green after a rain – on most other dryland soils the first rain tends to run off. Irregularities of the terrain (ie slopes, fissures and depressions), and even the soil's structural properties, become key players in moisture distribution. Some soils have a high run off when they are very dry, but become more absorbent once the top crust has been softened by precipitation or broken by hoofs. In these cases, a large first rain would be less useful than a small first rain followed by a larger one, even if the combined amount of rainfall were less than that of the single first large rain.

When it comes to soil moisture retention and plant growth therefore, the distribution of rainfall over time is just as variable and important as spatial distribution. Rain falls in showers of irregular intensity. One tenth of the total annual precipitation may fall in less than an hour. Small rainfalls may succeed for weeks only to be followed by a month without rain – a month which germinating crops would be unlikely to survive. For farmers and herders, no matter how heavy the first rain, it is impossible to predict whether the moisture in the soil will be sufficient to bridge the unknown period until the next rain.

The ubiquity of this variability from the perspective of a dryland farmer or herder cannot be overestimated. Not only is there variability in the start and end of the growing period, but also in the distribution of rainfall events, in the dry spells during the season, as well as between different periods within the same year, and between the same periods in different years.[22] Differences in the distribution of rainfall over time can result in differences in the incidence of diseases, weeds and parasites, all of which have a huge impact on the growth of crops or availability of pasture.

In the drylands, resource endowments (crops/pasture) will only exist at a given point in time – a time period that will change year by year, with sharp differences between even micro-niches. Differences at micro scales are highly significant, and effective producers need to be able to engage with this spatial and temporal variability. The productive potential of these resources, as well as their efficient and sustainable use, depends largely, or even entirely, on producers' micro-management and real-time adjustments.

The variability in the distribution of nutrients is not only between different areas or different patches, but is also found at lower scales. Obviously, different species offer different combinations of minerals and proteins, but nutrient differences are also found between plants of the same species, and between parts of the same plant. This is also true for crop residues, for example in cereals, where nutritive content is almost twice as high in the leaves than in the stems. There will also be a difference in the nutritive content of the same plant between the morning and the evening, that is, once the plant has had a full day of photosynthesis. Animal nutrition studies have found increases of up to 15 per cent in the nutritive content of the same forage between the morning and the evening.[23]

'Contrary to the view that scattered rainfalls are a limiting factor […] it may be regarded as a mechanism of controlling the availability of fodder resources at the growth stage that provides best nutritive value […] If rains would fall with equal distribution in time and space, the grass would develop beyond the stage of optimal nutritive value everywhere at the same time and herders could only exploit it for a short period.'[24]

The value in variability for livestock producers

When the dry season sets in across the drylands, the pasture standing on the range represents a given supply of fodder that will decrease as livestock feed on it until the following rains trigger new growth, but the nutrients in the fodder (proteins and minerals) will not be evenly distributed. In the drylands, pasture is usually better quality where the rainfall is only sufficient to allow limited growth. Whether in the Sahel or in Mongolia, the most nutritious fodder is that found closest to the desert, where overall fodder biomass decreases but it is richer in proteins, vitamins and minerals.[25] Where annual precipitation reaches around 1,000mm, the protein content of full-grown plants decreases by almost 10 per cent compared to arid areas.[26] Fodder plants are more nutritious at a specific stage of development, usually just before germination. After germination, the same patch of rangeland will have more biomass but be poorer in nutrients for livestock.

The time period at which pasture is consumed therefore determines the amount of nutrients it provides for livestock. For some plant species, the window of nutrient peak might be not more than a week or two. Measurements on pastureland in Kazakhstan found a drop in proteins of almost 5 per cent between the heading phase and seeding.[27] The high levels of variability in the drylands (rainfall patterns, soils, condition of the terrain) means that not only are there a variety of plant species with different nutrient peak cycles, but also the same plant species start their cycle at different times in different areas – even areas relatively close to each other.

As a general rule, herders are more concerned with the quality of the diet of their livestock (from grasses, shrubs, tree leaves) than the overall quantity of standing vegetation. The better the diet, the faster the herd reproduction rate and the better the milk. Livestock must be encouraged to make the most of the rainy season, when nutrients peak, so they can survive the inevitable weight loss during the dry season. But feeding well for as long as possible during the dry season can also significantly increase productivity. Herders are mobile precisely so that their herds can access the best quality grazing at all times.[28]

'It should be noted that livestock cannot compensate for poor quality by consuming more. On the contrary, with decreasing quality, activity in the rumen also decreases so that intake capacity decreases'.[29]

The end of the rainy season interrupts the development of all herbaceous plants on the rangeland. A relatively 'short' rainy season can cause an interruption on large areas of rangelands at the stage of tillering, turning this young short grass into unusually nutritious straw that will allow for further weight gains in livestock during the first two or three months of the dry season. An extra rainfall on tillering grass just before the dry season may decrease its value for livestock rather than increasing it.

A dry climate is an advantage when it comes to the harvesting and drying of crops. The dry climate means that farmers have more time to harvest, dry and transport their crops back to their homes for storage. In a humid environment, much greater speed and care would have to be taken to prevent spoilage.

"Grain can be stored here for 10 or even 20 years without any problem."

The value in variability for crop production

Drylands variability offers opportunities for adaptive crop farming. Variability in the distribution of rainfall over time allows for the distribution of the labour-demanding activities in farming, which is helpful under conditions of labour shortage. (In Africa, labour shortage is a typical bottleneck in farming that persists despite of demographic growth.) Weeding is one of the most labour-demanding activities, and a critical determinant of yields. Generally weeds are more vulnerable to a lack of moisture than well-rooted crops, and thus a growing season disturbed by a short drought may reduce the requirement for weeding.[30]

Interfacing drylands variability is also seen through storage – for which the drylands offer particularly good opportunities – enabling the delayed use of crops for consumption, or delayed marketing to take advantage of variability in prices. Thorough drying of harvested grains before putting them into store is critical. The greatest losses during storage are from insect attack. In the drylands, farmers have more time to harvest and transport their crops back to their homes for drying and storage. As the crop enters the store already dry, farmers can use sealed stores with no airflow, greatly reducing the risk of attack from insects.[31] In a humid environment, much greater care would need to be taken to prevent spoilage, and crops would have to be transported and stored immediately after harvest (therefore subject to labour bottlenecks).

In Africa, traditional Dogon granaries in Mali kept millet for up to 5 to 7 years. In the 1970s, post-harvest losses of millet in Mali and Senegal were in the order of 2 per cent in traditional on farm stores, compared to 10 to15 per cent in government central warehouses.[32]

In India, about 60 to 70 per cent of the food grain that is produced is stored in traditional or local storage structures at the household level.[33] In South India, sorghum is stored in a variety of structures, and is protected from insects by repeated sun drying and winnowing during the course of the storage season. There is also a local practice of mixing dried neem leaves with the grain to prevent insect attack.[34] Rainfed farming systems in India have always relied on stored food grains, tubers, and other tree-based staples for months on end, because they generally cultivate only one crop during the rainy season.

In north-western China, farmers keep several years supply of grain on hand, both as an insurance against crop failure from drought, and in order to be able to sell grain when prices are higher. Having ample stores of wheat, corn and other staples on hand also allows farmers to concentrate their efforts on higher value crops in a given year. Farmers harvest wheat in late summer and store it on the edge of their fields to dry. Stalk bundles are stacked in pyramidal structures open on the inside, speeding up the drying process by allowing the movement of air. When the wheat is fully dry, it is transported to farmers' courtyards for threshing and processing into flour. Farmers store grain in cave dwellings (yaadong), which remain cool even in the intense summer heat.

The 'messes' paradox *Drylands development as a skidding car ...*

Emery Roe, of the Center for Catastrophic Risk Management at the University of California, Berkeley, who has been studying structurally unstable contexts of operation for over twenty years, refers to them, in familiar terms, as 'messes'. These contexts are often close to us – like those responsible for services where reliability is paramount, such as power grids, air traffic control, or health – or dryland food production systems if one lives there or nearby.[35]

Contexts dominated by variability are described as 'messes' because they escape order in the conventional sense that associates it with stability and symmetry. They are 'messes' because they cannot be 'cleaned up' – ie reduced to a steady or predictable state. Trying to reduce their uncertainty only results in increased turbulence, that is more uncertainty, more 'mess'. This points to a paradox for decision making in the face of variability: 'The more mess there is, the more reliability decision makers want; but the more reliable we try to be, the more mess is produced'. [36]

The paradox described by Roe in his analysis of 'messes' is one that agricultural development work in the drylands has been battling with from its earliest days.

The more measures for ordering and simplifying were put into place, the more things seemed to spin out of control, and so the need for more simplification and control. Remember the car skidding at 70 miles an hour, described at the opening of this book: if the driver cannot resist the desire to feel in control, and goes for the brake, the structurally unstable context will make the car behave even more unpredictably, escalating the danger. Now imagine stretching that dangerous instant into decades, and you will have an analogy of the history of drylands development. The car is skidding and the foot is on the brake.

Variability can be managed, and is managed daily in many critical contexts all around us, but it needs to be handled realistically. Realistic managers respect that variability poses limitations on control, and refrain from the urge to govern all discrete operations. Instead, focus is placed on the capacity for real-time adaptation to the contingencies that arise unexpectedly and uncontrollably – avoiding the bad or worse consequences while taking advantage of the opportunities that variability can also offer. Roe describes this as 'managing the needful under always-dynamic circumstances'.

The 'messes' paradox in the history of drylands development

Irrigation and mechanisation schemes

Elimination of slash and burn

Replacement of domestic animal diversity with few standard breeds

Regulation of mobility and sedentarisation

Controlled stockings

Rotational grazing

Privatisation of the commons

Introduction of monocultures

... and the U-turn. A new understanding of the role of variability in drylands

Over the decades, practitioners and researchers working in the drylands have raised concerns for the mismatch between the repeated attempts to reduce uncertainty to a manageable simplification, and the observable increasing of turbulence in practice. For example, long before the concept of resilience was adopted in development work, ecologists pointed out that 'comparison of the dynamics of various savannah and other natural systems leads to a conclusion that the resilience of the systems decreases as their stability (usually induced) increases.'[37]

Leaving aside their individual differences, these concerned voices all hinged on a need to understand variability as an inherent feature of the drylands – a functional element within a dynamic system, rather than a disturbance within a system naturally prone to a state of stability. In the late 1980s and early 1990s a particularly well-coordinated effort made this case with regard to pastoral development in Africa, highlighting the limitations of using conventional assumptions of equilibrium developed from the experience of temperate environments.[38] From this alternative perspective, local production strategies that in the 'equilibrium' model had appeared chaotic, irrational or disruptive – for example pastoral mobility – now made sense; while ordering processes aimed at 'returning' the system to a state of stability now appeared problematic.

'The producer's strategy within non-equilibrium systems is to move livestock sequentially across a series of environments [...] exploiting optimal periods in each area they use [...] Herd management must aim at responding to alternate periods of high and low productivity, with an emphasis on exploiting environmental heterogeneity rather than attempting to manipulate the environment to maximise stability and uniformity.'[39]

During the last twenty years this U-turn in the understanding of the drylands has reached governance and policy-making circles. At the global level several UN agencies, national development agencies, conservation agencies and the World Bank have published documents reflecting the new understanding.[40]

While descriptions of pastoral strategies following the change in understanding have highlighted their role in turning dryland variability into an asset for food production,[41] this dimension has not yet been so explicitly addressed in the analysis of dryland farming. Plenty of descriptions have emphasised the importance of flexibility, pointing out that farmers 'cultivate diversity.'[42] The traditional representation of dryland variability as a structural 'limitation' to agriculture remains predominant however, contributing to the interpretation of empirical evidence on farmers' expertise in managing variability as examples of 'coping strategies' in the face of a problem.

Focusing on variability as structural makes it easier to see dynamic correlations, and the use of them if possible, rather than being distracted by the (hopeless) effort to 'keep things still'. Abandoning the conventional representation of variability as a disturbance allows us to see how, in practice, it can also bring opportunities. As in the case of the unstable systems studied by Emery Roe, dryland variability cannot be reduced to a steady state, but it can be managed.

Variability in dryland environments is valuable

Drylands are commonly defined as having low average rainfall. Although this is true, average rainfall is not the only determining factor in dryland food production: variable distribution is equally important. Rainfall follows highly variable patterns, with temporal and spatial concentrations merging with the diversity of dryland landscapes and exploited by adaptive strategies. These can lead to substantial crop and pasture growth.

Farmers and herders in the drylands may be unable to predict exactly when rainy seasons will start and end but they know that when it does come it will create a resource legacy of crops and pasture that will be nutrient rich. By contrast, agricultural development has sought to alter the unpredictability of dryland environments into some form of temperate stability.

The opportunities for production in the drylands are not inherent to the environment, but depend on the producers' relationships with it. Dryland producers make real time adjustments to their production strategies, working with the unpredictable resources to create advantages. The next section shows how dryland variability is being managed to create successful local food production systems.

"Rain is unpredictable; it is only God who can tell when it is going to rain and where, this is normal for pastoralists. In times of abundance when it has rained and there is so much fresh milk from the livestock, we work to prepare enough butter from the milk. The butter is stored until the dry season when we can sell it for a high price. The butter is also served with our food during the dry period when there is no fresh milk to feed the family, this ensures proper and balanced diet for all including children."

Halima Gollo
Pastoralist Woman from Merti Sub-county in Isiolo, Kenya

Thirty years ago this area in Ethiopia used to be grassland, but the large-scale commercial farming introduced to try to control variability has turned it into a dusty plain.

Part 2

Drylands variability and food production

"The fundamental work of our cooperative is to integrate rangeland, capital and livestock. We have succeeded. We manage our rangeland, breeding rams and breeding ewes together, and we use the rangeland together. We don't stay in one place throughout a year but use the rangeland according to its suitableness. We do not sell lambs as meat products, but raise them until one to two years old and sell them as breeding rams or breeding ewes at a much higher price."

Haobisihalatu
Mongolian, 50 years old, Chief of Harigaobi Gacha and executive of Harigaobi cooperative

Next Monday there is a meeting that you absolutely cannot miss, however the exact time will only be communicated on the day. Would it be a reasonable course of action to keep the entire day free, at least until you know more? In doing so, you will introduce variability in your schedule to interface the variability in the time of the meeting. An alternative could be to schedule only activities that can be cancelled at the last minute, or secure substitutes that are available at short notice. The range of alternatives, not all equally good, depend on (variable) constraints and availability of resources.

The variability of the drylands is managed in much the same way as personal assistants manage work diaries, by interfacing it with variability – in this case, variability in the system of production. In this part of the book we show the ways in which dryland food production and livelihood strategies are harnessing variability and managing it to their advantage.

Variability results in sequences of unpredictable events, in familiar or unfamiliar patterns, that call for rapid responses. By definition there is no fixed way of interfacing variability. There are no permanently 'best' solutions in the face of variability. The 'best' solution is securing a dynamic variety of partially overlapping solutions and the option of real-time adjustment.

Van Gujjar herders in the Himalayas meet to discuss migration logistics

Farmers in the drylands of northwest China diversify their 'portfolio' along longer cycles of several years through crop rotation. They use a number of strategies, depending on how much land they can cultivate, and adjust them in order to optimise the use of moisture. In the middle portion of land, which appears to rise like an island, one can see different colours of ploughed earth. The whitish section on the far left was planted last year and is being idled this year. The greyish section next to that was planted earlier this year and harvested. The grey portion is currently being idled and will be planted again the following year. The coffee coloured section has just been ploughed, while potatoes are being grown in the section directly to the right of the newly ploughed land. In the foreground to the left are terraces with grass on them that have been idled for at least two years.

In dry mountain areas of northern Ethiopia, farmers create micro-level variability in the distribution of rainfall by deliberately leaving a lot of stones in their fields (those not big enough to disturb the plough). To the agricultural engineer, the fields look terribly 'untidy' – and the farmers 'lazy'. But in heavy showers the stones break the kinetic violence of the drops, decreasing the run off and increasing the absorption of moisture. Raindrops run over the stones and collect around, underneath and in between, creating micro concentrations of moisture. When farmers sow (by hand) the seeds collect precisely where the stones have created a concentration of moisture. The stones also 'space' the seeds better than can be done in sowing, saving the labour involved in 'thinning', and protecting the sprouts from wind and sun. The most sprouts come out from just beneath a stone. [43]

Harnessing variability for crop production

Is it better to put your hard-earned savings in a guaranteed low-rate investment fund, or to gamble it for high profits on the stock market? The best funds are often those that build a variety of portfolios, allowing for relatively safe and dynamic combinations of both strategies. It is the same with dryland crop farming.

A farmer who can rely on a growing period of 90 days would probably want to maximise valuable crops that can be grown within that window of time. But what if behind the 90-day mean growing period in the region, the actual window on the farm is known to be anywhere between 60 days and 130? And what if the exact length of growing period can only be known at the end? A 90-day cropping strategy could result in a loss of profit if the actual growing period turns out to be substantially longer, or in a complete failure if the actual growing period is much shorter than the mean. One does not need to be a farmer to appreciate that a low-yielding crop that completes its cycle will represent a higher yield, than a high-yielding crop that does not make it to harvest.

Whenever they can, specialists in dryland crop farming try to manage the variability in the environment by connecting it with variability within their production system. Interfacing variability means cultivating a 'portfolio' of crops aimed at capturing maximum yields at a variety of lengths of growing period. Diversifying cropping patterns and intercropping within the farm, or even within the same field, can also help managing spatial variability in soil moisture and soil composition, to the producer's advantage. The fields themselves are also usually scattered across different micro-climatic zones.

A diversity of non-planted vegetation with economic value (eg trees, shrubs and fodder) can also be selectively promoted on the farm to create multiple sources of benefits throughout the year (eg food, fodder, medicines, construction materials, but also 'services').

In a well-known 'farmer-managed natural regeneration' (FMNR) system launched in the 1970s in southern Niger (adapting from 'centuries-old methods')[44] the stumps from among the mature root systems found in fields (sometimes as many as 200 per ha) are helped to grow into proper trees while the land around them is farmed. Farmers interviewed in 2006 claimed that the trees reduced evaporation and protected young crops from the sandy winds.[45]

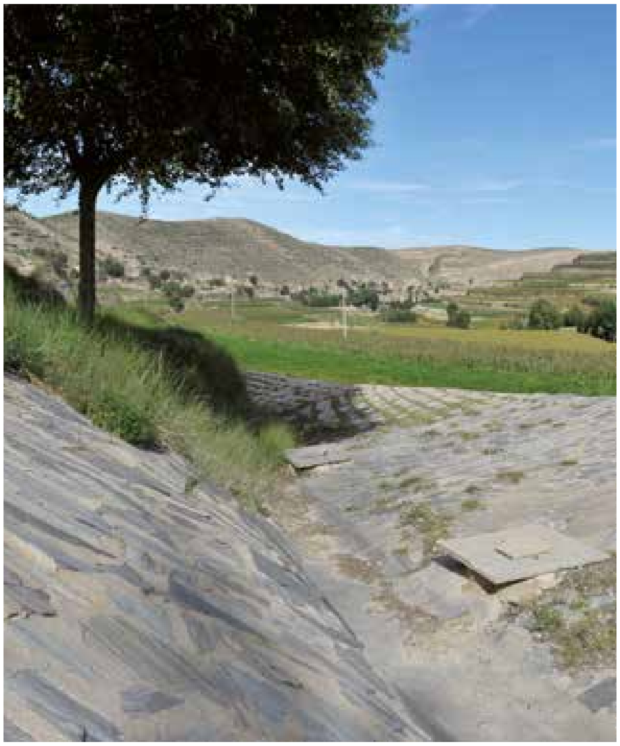
Several cultivars and even sub-varieties (landraces) of crops are usually selected and maintained to cater for a range of different environmental conditions, as well as for different functions within the production system. As variability can be embedded for every function, a variety of 'functions' greatly expands the potential for diversifying the portfolio.

By using 'layering' or 'multi-stored' polyculture, the taller and stronger plants break the violence of rainfall, and from them water drops more gently and for longer on the lower levels. In the three-layered system of oasis agriculture, the shade from the upper layers slows down transpiration at the lower layers and evaporation at ground level.[46]

In flood-recession cultivation, variability can be exploited directly, whilst water harvesting allows the interfacing of temporal variability in rainfall or even in the availability of drinking water.

"Diversification means that farmers can choose when, what and how much to plant based on the situation. Years of good weather, which enable all crops to grow well and provide a good harvest, are very rare. The farmer doesn't know what the weather has in store for him, so he plants millet in one plot, maize in another, and in a third plot he plants wheat. Now, if he can get a good harvest for all his crops it's wonderful; but if the wheat crop fails, there is still the maize, and if the maize crop fails, there is still the millet. It is an excellent strategy. Diversification also enables farmers to avoid the risk posed by pests and diseases. With industrial agriculture, these risks are very hard to avoid. Besides spraying pesticides and herbicides, what other option do you have? In this land no herbicides have been used. There are weeds, but the crops are still dominant and it looks like they will have a good harvest."

Professor Wei Huilan, Lanzhou University, Gansu, China



Rainwater harvesting water tanks have been built adjacent to fields; with roads, hillsides and concrete surfaces all serving as catchment areas: Rainfall stored during the previous autumn and winter provides enough water to irrigate crops during the critical period before the arrival of the summer rains.

"Water tanks are like wealth. Without water, how can you survive?"

Concrete water tanks have become an indispensable asset in rural areas. Supplemental irrigation via rainwater harvesting has led to substantial increases in yields of grain crops (especially corn and wheat) and fruit trees (eg apple, pear and peach) in some localities.

Case study

Using rainfall variability for crop agriculture in NW China[47]

Agricultural intensification in China (ie ignoring drylands variability) has led to extensive pollution of ground water sources and rivers, causing pollution of soils and crops that depend on surface water. In dryland areas that receive short intensive rainfall, however, the expansion of rainwater harvesting is using rainfall variability to successfully harvest water and grow crops. Farmers use the strategy of optionality to diversify the number of crops grown over different seasons (such as spring and autumn crops), ensuring that a harvest is possible even when some crops inevitably fail during drought. The extended dry season is also an aspect of variability: used to dry crops more effectively and allow for longer storage and more marketing options for farmers.

The Loess Plateau is one of the largest dryland regions in China, with soils derived from loess – a fine windblown material originating from Central Asia. Despite a number of qualities that make them well suited to agriculture, loess soils are extremely susceptible to erosion when the protective cover of vegetation is removed.[48] The plateau has sparse vegetation cover, severe soil erosion and gullying. Groundwater is effectively unavailable due to high pumping costs, low annual recharge or high levels of salinity. Most high altitude hillside fields are located far away from large river systems; and where sufficient surface water resources exist their quality is poor due to pollution and salinization.[49]

Farmers in China's semi-arid northwest now rely on rainfall to supply their household needs and support agricultural production. Precipitation is low (250 to 550mm) and droughts are common, but the issue for agriculture is not so much the paucity of rainfall but its intensity and timing. Rainfall tends to be concentrated in intense thunderstorms, with nearly two thirds of the annual precipitation occurring between July and September. Crops planted in late March and April gradually deplete the available soil moisture, whilst spring/summer crops such as wheat (limiting period May to July) may fail entirely if the rains arrive late.

In Gansu province, cisterns and ponds for water storage have been in use since at least the Ming Dynasty, but harvesting has seen a resurgence recently as rainwater becomes the least polluted water source available. Rainwater harvesting works in recognition of climatic variability – using variability rather than attempting to combat it. It does so by resetting the availability of water in spatial and temporal terms on a small scale. During the rainy season water is stored in tanks or ponds, and utilised when rainfall is scarce to provide water for crops – particularly grain, vegetables and fruit trees – using drip and spray irrigation systems. Concentrated rainfall – occurring through thunderstorms – is particularly beneficial for water harvesting: it allows for runoff to first 'wash off' the catchment surfaces before the collection of significant amounts of water.

The most common water storage facilities in northwest China are underground tanks lined with concrete or clay. The tanks are usually situated inside or adjacent to the courtyard for household use, and above fields for irrigation purposes. A high level of craftsmanship is required for both traditional and modern tanks in order to prevent seepage and subsidence. Tanks are below ground to maintain water quality – ensuring low temperatures in summer, and preventing freezing during the winter.[50]

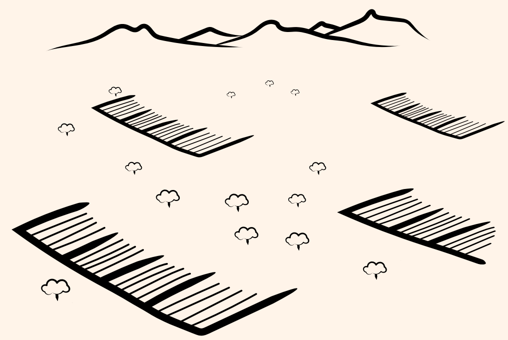
'Farmers can also respond ex post to climatic conditions by evaluating in mid-season whether crops on one plot are likely to fail, then adjusting production of substitutes at another site. If a lowland rice crop is destroyed in a flash flood, the family can survive by substituting cassava. Additional cassava is immediately planted to replace the depleted insurance supply'[51]

'In farming, decisions about what to plant, and where, are reviewed in the light of the previous year's performance, of expected rainfall, of insects, of price movements, of the amount of food still remaining in the family granary, and of the labour available'.[52]

'Farmers in the semiarid climates of the West African savannah, like herders, value temporal flexibility. For example, shifting cultivation and several types of rotational farming exploit the variable productivity of the resource base. In the dryer areas, farms may actually move around from year to year. In Niger, one observer described the farming system as "agricultural nomadism" in view of the continuous movement of farms in search for fertile soils.'[53]

Traditional 'Teras' cultivation

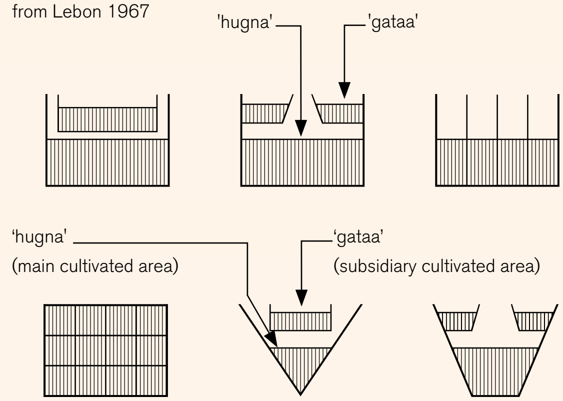
Eastern Plains, Sudan (artist's impression)



Various pattens of 'Teras' systems

(Butana – Eastern Sudan)

from Lebon 1967



Approximately 10,000 ha of teras have been constructed for impoverished farmers since 2007 under various agencies in Sudan – both international and national – who have come to appreciate the merits of the tradition for growing sorghum.

Case study

Opportunistic response to variable rainfall: the sorghum teras of Sudan[54]

The length of the rainy season in Sudan is usually three to four months – depending on the region – with the rest of the year virtually dry. Rainfall occurs in isolated showers, which vary considerably in duration, location and from year to year. Rainfall ranges from 3,000mm in the north to 1,700mm in the extreme south of what is now South Sudan. Much of eastern Sudan uses in situ rainfall conservation, and in the very extensive semi-arid and arid zones, a variety of water harvesting techniques are used.

Sudan's indigenous teras system has proven its worth over centuries. A traditional teras impounds a field with a three-sided earth bund, capturing surface runoff from an external catchment above the plot. Each teras – sometimes subdivided within by smaller bunds – is usually around one hectare or a little more in size. The bottom bund, sited approximately along the contour, is longer than the main upslope 'arms', which are set at right angles, embracing overland flow from the upslope external catchment: the catchment to cultivated area ratio is in the order of 2:1. The earth bunds are between 0.35 and 0.50cm in height, and the base width from 1.5 to 2.0 metres. Traditionally these were constructed by hand, though mechanization has recently been introduced in places. Management of the plots is on an individual, or family, basis. Seasonal maintenance depends on the degree of damage caused by runoff, but is relatively low cost and straightforward.

The gentle gradient of the teras, with their bund at the bottom to capture the runoff, is almost invariably planted with sorghum, as this is the cereal crop that can best withstand both drought and flooding conditions. Depending on the differing amounts of rainfall (unless there is an extreme drought) the teras produce a gradient of sorghum production, with the mature taller and stronger sorghum towards the bottom of the teras used for human consumption and any 'failed' crop higher up the slope fed to livestock. Indeed there is often a very distinct continuous gradation from the top of the impounded area (with poor crops) to the bottom (with good crops). During flood years, it may be the bottom of the plot slope that is the 'failure' due to waterlogging.

The slope of the teras is the key to its success because the system is one of maximising opportunity rather than seeking uniformity in sorghum production. The system works in good rainfall years and also avoids uniform crop failure in bad years. And by feeding the sorghum residue to livestock, even a 'failed' crop can represent significant fodder production. The productivity of the sloping transect illustrates how crops respond to harvested runoff under a situation of differing water availability.

Teras continue to be the mainstay of non-irrigated agriculture in eastern Sudan. They tend to expand in number during and immediately after years of good rainfall when agricultural investment activity is stimulated by healthy yields. According to the State Ministry of Agriculture they have increased over the past 20 years and especially recently. The system illustrates how many nomadic livestock keepers in fact, make use of their spare time/labour to undertake opportunistic farming. Similar cropping 'calculated gambles' can be found in Baringo and Turkana in Kenya.

"Cotton is our major crop; it grows well here. Our ancestors have grown cotton over hundreds of years. As the 'white gold' became more valuable – brought more money, we also fell for the temptation and by the early 1990s there was only cotton here. When WASSAN reminded us, we agreed that our ancestors never grew cotton as a mono-crop. It was always mixed with gram or millets – the very millets that were part of our food just thirty years ago. That became our answer; we wanted to eat millets again. We wanted to grow our own millets in our own fields. The potential conflict with the cotton trader was as expected. We used to get many forms of support, especially cash and agricultural inputs when needed, from him.

The trader did not see merit in our move to reduce the cotton area and increase the area sown to millets, maize, vegetables and grams.

Overall, the productivity per acre is higher in each field, though 25 per cent of the land has gone to other crops. Cotton yield used to be 5–6 quintals per acre. Now, with the mixed crop stance and new agronomic practices (some of these are very much our old practices), the yield is 8 quintals per acre (even during a tough year like 2013–14). During a good year (like 2012–13) the yield now is about 9–10 quintals; it would not have gone above 7 quintals if we had followed the earlier mono-crop cotton."

Farmers in Mallapoor village, India – interviewed in January 2015.

Left: Wheat and sorghum (in January) sown after cotton harvest, with the red gram border crop bearing pods.

Right: Local maize (dual-purpose varieties).

Case study

Rainfed farming in India – Reviving mixed cropping and millet production[55]

Almost a century ago there was considerable awareness of variability within Indian agriculture, including: the immense opportunities that diversity offered for enhancing productivity; adaptation and learning at the village level; and need for integration of various scientific and local practices.[56] The Famine Commission of 1881 had also demanded that 'the Government should first get thoroughly acquainted with Indian agriculture before deciding how to improve it using modern scientific methods and maxims'.[57]

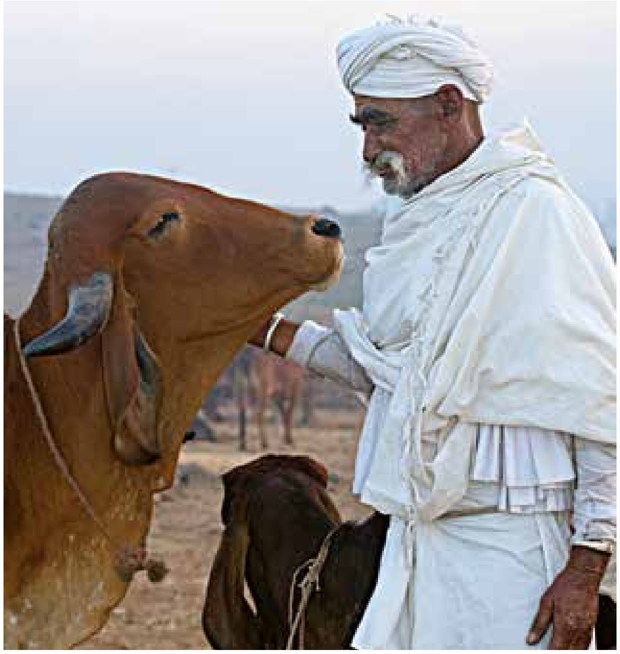
The XII Five Year Plan of the Government of India proposed a National Programme of Rainfed Farming (NPRF).[58] It was meant to harness high inclusive growth potential by enhancing 'untapped agronomic and management innovations'. But the capacities to implement the NPRF are missing in the current highly centralized and supply driven formal Science & Technology and administration of agriculture.[59] Yet, there are some cases that demonstrate capacities for agronomic and management innovations. One such case is the revival of agronomic knowledge and millets based mixed cropping systems in Mallapoor village in Uthnoor mandal, Adilabad District in Telangana.

By the early 1990s, Mallapoor village had shifted crop stance completely to cotton ('white gold'), plus some soya and red gram, having given up traditional crops and cropping systems. Increasing destitution and indebtedness at the hands of the middlemen handling the cotton output had become major issues. Recognising that agronomic and natural resource based knowledge is necessary to build secure bridges between agriculture, nutrition and the environment;[60] WASSAN and the DHAN Foundation began working with farmers in Mallapoor.

After much painful churning between farmers, NGOs, private traders, rural banks, and public sector extension services, in 2010–11 Mallapoor overhauled its focus on cotton, set to work on improving soil moisture retention, and devoted 25 per cent of its arable land for millet-based mixed cropping systems. Today, the village of 7 hamlets, 82 families in all, has now 7 dug wells, one tube well and revived a tank (the Dharmasagar watershed under the Indo-German Watershed Development Programme) with NABARD support. As farmyard manure and biomass application has increased, the number of cattle has also increased, from about 20 in 2008 to 100 bullocks and cows in 2014. Previously the village sold 10–12 cartloads of cow dung, but now the village uses all of it on its own land. Labour sharing and seed saving norms have also been introduced.

Today, every household in Mallapoor village is food and nutrition secure: a reflection of the wellbeing of their fields, their lands, water and livestock. The cost of cultivation has declined, with chemical fertilizer and pesticide application each reduced by 50 per cent and manure increased by 50 per cent. Mixed cropping of millets, pulses, vegetables and tree crops, alongside the production of cotton, has yielded more cotton, food, and fodder. The new resilience was demonstrated in 2013–14 when the poor and erratic monsoon caused only a marginal decline in yield, whilst farmers in the three surrounding mandals faced massive crop loss. Translating and transferring these community-based innovations to the mandal, district, and state levels, however, remains a daunting task.

Livestock production models often assume linearity of cause and effect, and tend to focus on one variable, the conditions of the range – usually represented in abstract as estimated availability of fodder biomass (the basis for calculating 'carrying capacity'). But there is no linear relationship between fodder being available and fodder being consumed.



The Maldharis of Maharashtra rear the famous Gir cattle – a sturdy animal that can walk for days with low fodder and water inputs, resilient to drought and disease, and adapting easily to diverse production systems. "We select those calves who are red in colour with long ears, a long tail, a well defined and prominent hump, and a large well-shaped head. The animal must also be tall with strong legs. The performance of the mother is also taken into consideration while selecting a bull calf, and calves of cows which are good milkers, of easy temperament, and who are not prone to diseases are preferred."

Harnessing variability for livestock production

How do you plan your business if you cannot predict your resource basis? How do you match means of production that take 3–4 years to develop to full performance, with operating conditions in which no year is the same as the previous one? Above all, how do you make sure you are able to access resources that become available in ephemeral concentrations at uncertain times and in uncertain places? In other words, how do you manage variability and produce a surplus, rather than simply running to stay still? Like the producers specialising in crop farming, whenever they can, herders try to manage the variability in the environment by interfacing it with variability in their production system.

Working with the herd

To a botanist, 'grass' refers to a mixed population of mostly herbaceous plants. To an animal scientist, grass is energy. To a herder, grass is food for his or her livestock. Energy is a versatile and elegant concept, but it does not just jump into a cow's mouth. For the energy stored in grass to be of any use to livestock, the animals have to first eat the grass.

It is usually taken for granted that cows or sheep will naturally feed on grass, and eat as much as possible of it, but it is not nearly as straightforward as that. (Cattle that have been raised in feedlots for generations are known to struggle with hunger for months if shifted to pasture: despite being surrounded by palatable fodder they do not know what to do with it or how to do it well enough.[61]) Ruminants can be disturbed by parasites, noise and heat, or from having to negotiate a difficult terrain or a new location, or from threatening behaviour from other animals in the herd.

Fortunately ruminants can also get used to problems, or learn how best to deal with them. They learn to feed on new plants, and even improve their efficiency in extracting nutrients, but they cannot compensate for a poor-quality diet by eating more. The rumen can only process a given amount of fodder in one cycle, and an unrewarding post-digestive experience abates the appetite. Thus, when faced with a poorly nutritious diet, ruminants end up eating less rather than more, losing weight quickly.

For the best part of its history, starting at the time of the industrial revolution, animal science has represented ruminants by analogy with machines. Getting grass into a cow however is not the same as getting petrol into a car (or even a lawn mower). Livestock have fears, curiosity, likes and dislikes. They can be tired, stressed, and bored. They can have social attachments, with 'friends' and 'adversaries', and they can feel lonely. They can be anxious, alert, moody, aggressive or cooperative, with all these states having an impact on their feeding performance.

For livestock systems that represent animals by analogy with machines – assuming simple and stable relationships of cause and effect – such variability is something that gets in the way, a disturbance. In dryland pastoralist systems though, variability is embedded into the production system – connecting it with the variability in the environment: the variability in livestock is therefore an opportunity to work with. The goal of the herder's work is to help livestock make the best of the rangeland resources, persuading them to take in as much energy as is possible from the available, but ephemeral, nutrient concentrations.

"What sheep need to live is more than forage only. Just like people who could not live on rice only, they also need vegetables and salt. Sheep need water as well as forage. Water from wells is too cold. Springs are much better; (because) they are neither too hot nor too cold. Sheep need water when it's time to drink, need salt when it's time to lick salt, and thus (only when these are satisfied) they gain good weight. The rangeland I contracted is suitable for summer use, but not suitable for winter and spring. There are needle grasses (stipa spp.) on some pastures. In September and October we move to Bilige's pasture. His pasture is suitable for autumn. There is a spring water point at his pasture. When the spring water is frozen, we move to Nasuge's pasture. Nasuge has a well at his pasture. The grasses there are coarse and thick. The snows are soft on such pastures: they will not be compacted into ice after grazing.

Hugeqiletu Mongolian, 36 years old, vice chief of Hulun Nuur Gacha

Not all cows are able to feed on short grass without ingesting a lot of sand, which makes them ill. In the Sahel, in order to gain a few extra days of green fodder, the Wodaabe breed their cattle for small muzzles, and promote within the herd a learned, unusual grazing technique (identified in their language by a specific term), consisting of plucking the grass with the front of the muzzle rather than ripping it with the tongue.

Stretching the 'length of growing period'

Grazing systems in the drylands are boom and bust. Livestock lose weight during the dry season and gain weight during the wet season. The extent to which weight is lost and gained in a given year is variable, depending not only on the conditions of the range but also on the work of the herders, the specialisation of the production system (including the animals) and the space available for operating it, and the condition of the herd from the previous year.

Herders in pastoral systems use management strategies aimed at maximising the length and impact of the period in the year in which animals can put on weight, while minimising the length and impact of the period when they can't. One of the most frequently recorded strategies in this sense consists of 'stretching the length of the wet season'; not in absolute terms but relative to the experience of the herd, using mobility.

Mobility allows herders to 'meet' the rains as early as possible, and follow them for as long as possible. There are different ways of doing this. Some pastoralists in the Sahel (eg in Chad) travel maybe 200 kilometres south to meet the rains a few weeks earlier, then turn around following them back north in a 1,000–1,500 kilometres journey.[62] Others, like some Wodaabe groups in Niger, exploit variability at a lower geographical scale, moving within a distance of 200–300 kilometres in a combination of south-north/west-east orbits, heading for the quickly-shooting grass species on sandy soils (eg Cenchrus biflorus) at the beginning of the rains, then moving to clayey soils where shooting is slower, so as to always keep the herds on the new grass patches peaking in nutritional content.[63]

Breeding and management strategies promote selectivity in feeding, and competence in building variety in the diet; with a preference for animals prone to grazing lightly on only the best bits – and skilled in mixing grasses with herbs, shrubs and even tree leaves – in ways that complement the nutritional properties of each. Herding itineraries are chosen with care to keep for last those areas where prevailing plant species or climatic conditions mean that green fodder is available even after the setting in of the dry season. Light grazing might be followed by a second wave of grazing, once the plant has produced new buds. This can be done by the same group of herders, or by different groups following complementary strategies (eg Wodaabe and Tuareg).

Other ways of embedding variability in the livestock production systems are: keeping a variety of species with different feeding requirements and specialisation; keeping a variety of 'lineages' or 'types' within the preferred breed in each species; and also keeping a herd with different patterns of behaviour and performance.[64]

The nutritional logic behind these strategies has also been recognised in the most specialised types of pastoral systems in Europe. A recent book on shepherding in France describes how itineraries are carefully designed in order to 'tease' the animals' appetite and maximise their intake of energy, thereby obtaining energy intakes by flocks higher than the maximum levels estimated for the area by scientists.[65]

The link between the Sámi, indigenous to northern Fenno-Scandinavia, and reindeer dates back thousands of years, even if Sámi reindeer pastoralism is more recent. By the 17th century, herding of reindeer had become a widespread part of a flexible and varied livelihood portfolio, which also included hunting on the plateaus in winter, and fishing in the summer and autumn.

The same piece of landscape can represent either a benefit or a disadvantage to the reindeer, depending on circumstances. For example, relatively thick birch woods (*roavvi*) are beneficial during early winter as they protect from wind and avoid snow packing, as well as allowing reindeer visual 'protection' due to the frost that sticks to branches. Yet, this habitat becomes limiting as winter progresses: Towards the beginning of the spring-winter, reindeer move to more open landscapes that allow them better access to areas with thinner snow layers that are easier to dig through.

Case study

Sámi reindeer pastoralism – harnessing variability in the cold of Norway[66]

In Finnmark (northern Norway), where most of the country's reindeer pastoralism takes place, discontinuities in relief and climate have a strong impact on the practices of seasonal resource exploitation. There is a climate gradient between the Norwegian Sea coast and the inland plateau. On the western coast, affected by the Gulf Stream, the mild and moist air produces cool summers and mild winters. On the inland plateau, on the other hand, continental harsh winters and hot and moist summers are the norm.

The difference between coast and inland is accentuated by geology: degradable bedrock rich in nutrients supporting lush vegetation on the coast; and acidic oligotrophic soils promoting mat-forming lichens in competition with vascular plants inland. The topography and patchiness of the landscape creates numerous niches that are used for various purposes by reindeer in their annual cycle of migration from the inland winter pastures to the coastal summer pastures.

In order to help access better nutrition for the reindeer, the Sámi reindeer herders have developed a sophisticated way of assessing and harnessing the numerous variations in the plant communities, microclimates and topographies that these landscapes provide. They conceive the pastoral year as a complex of eight seasons, roughly translated as: spring, spring-summer, summer, autumn-summer, autumn, autumn-winter, winter, and spring-winter. The rationale is that this reflects the great variations in the pastoral needs (of reindeer and people); but this seasonal division is merely the beginning of the detailed understanding that is needed about the patchy resource landscape, and the high risk of harm that can occur in this harsh environment.

During the cold season, the reindeer may choose key resources such as river valleys for good quality, preferred food, but they soon abandon these areas as the snow covering them becomes too packed due to strong winds or trampling. Later on, as mountain ridges (*čearru*) lose their snow cover, they move up to higher altitudes. The reindeer's choice of micro-topography has as much to do with finding nutritious food as with avoiding disturbance. Avoiding disturbance refers to the reindeer's degree of tameness, and their attitudes toward herders, predators, insect harassment, and weather (eg winds can act to reinforce or calm the migratory instincts of reindeer at particular points in time). Movement patterns focused on finding nutritious foods, on the other hand, are a reflection of the types of alternative plants available, their accessibility, the food that was available the previous summer (ie if they have had enough grazing) and the social structure of the flock. The relative rank of the animals in the herd influences their ability to defend the craters they dig in the snow to access lichens and other plants.

In the background of all these choices on niches, and the timing of the mobility between them, is the herder – who guides the herd with varying degrees of intensity. In order to decide on the best herding strategies, herders rely on vast amounts of previous local knowledge and recent case histories regarding micro-climate (eg how precipitation and wind patterns have evolved in a certain location during recent weeks or months), topography, meteorological predictions, and movements of neighbouring herds. To allow for a variety of contingency plans against fluctuating and potentially disastrous environmental variability, an ecologically varied pastureland (*suoitce*) is the best strategy for harnessing the best opportunities at the right time.

"In the morning the landowner's field is covered in organic manure. On the fields where the sheep sit, the yield is twice as high as on the fields where they do not sit. The effect of the dung lasts for three years, the effect of urine for one year and its impact starts immediately. At this moment, the people are not giving anything because the crops are still standing and they are afraid we will destroy something. As soon as the crops are cut, their attitude changes. They give us 40–50kg of grain per day plus tea, sugar and bidi then. Some people even give 60kg of grain per day."

Sonaram Raika (Patel) from Kotar

If a farmer puts a fence around his field, he protects his property rights against the risk that someone might steal the fruits of his labor. He is establishing an exclusive right ex ante. The more valuable and certain the income stream, the more valuable the fence will be to him. In other words, he will have a strong incentive to establish an exclusive property right to a particular piece of land. But what if the income stream is highly uncertain? The fence will be less and less valuable to him. What if the uncertainty is so substantial that it would make more sense to find out about the event first and then adapt to it? If he could be flexible, it would allow him to learn and help to ensure a more certain income stream in that way. To capture that income stream, he would want a property right which allows him to adjust ex post, capturing the benefits of flexibility. Think of a nomad wanting to move his herd after observing where the rain has fallen and the grass is greener.

In the literature, far too much attention has been given to the first type of property rights—territorially exclusive property rights which protect against ex ante risk. Far too little attention has been given to property rights which capture the benefits of learning, optimize flexibility, and deal with ex post risk. This book sets that record straight.

Rogier van den Brink
Lead Economist and Program Leader for the Macroeconomics and Fiscal Management Global Practice of the World Bank

Harnessing variability through crop-livestock integration

Dryland variability involves several dimensions and scales; it is therefore not surprising that successfully connecting with this variability should involve matching levels of complexity. In the drylands there is virtually no form of small-scale agricultural production without some kind of integration of livestock keeping and crop farming, even if integration has taken many different paths.[67] At the regional and inter-regional scale, the integration between livestock keeping and crop-farming strategies creates opportunities for the exploitation of comparative advantages related to different agro-climatic zones and specialisations. A great variety of customary institutions have been developed to regulate these kinds of integration, reflecting deep historical roots and their economic importance.

Farmers in Africa will rent their livestock to long distance herders, who, for a specified share of the outputs (calves and/or milk) take them to otherwise unreachable high-quality pastures and away from the agricultural areas during the farming season. The strategy allows for a diversification of the asset portfolio across ecological zones for farmers, and increased access to capital for herders. Similar forms of 'investment opportunities' have long been observed also for urban investors[68] and have become increasingly popular over the years.[69] Entrusting livestock to herders during the farming season frees labour at the farm at the time of the year when labour demand for cultivation peaks. This introduces variability in the supply of labour to interface variability in demand associated with unpredictable rainfalls.

In another dimension of regional and interregional integration there are 'contrats de fumure' (manure contracts) that farmers make with mobile herders to graze their livestock on the fields once the animals can no longer damage the crops. The exchange may be crop residues or water access in return for the benefits of animal manure and access to fresh milk. In the 1970s an analyst, describing the benefits of regional integration in northern Nigeria, noticed that the Fulani's livestock under manure contracts also actually 'work the fields' for the farmers: they 'break up the cultivation ridges and strip the stalks which are later used for fences and house construction, thus saving the people a lot of effort'.[70]

Variability in the pattern of integration is reflected in the variability of the arrangements around entitlements to resources. Economists discussing this level of integration highlight that it 'avoids the risk of negative externalities between cultivation and herding activities: under the rental agreement, grazing cattle do not interfere with cultivation since the farmer gives cattle to the herder who takes them along on his transhumant movements. The contrat de fumure properly demonstrates that exclusive cultivation property rights need not be defined for a whole year; they only need to be secured for the duration of the growing season […] Outside of the growing season, both farmer and nomad benefit from the establishment of a different set of property rights'.[71]

Specialising in taking advantage of fodder resources that become available in unpredictable spatial and temporal sequences, while optimising their use (eg by reaching them at the best time, or by sequencing waves of use following by complementary strategies), requires particular forms of land tenure.

The Maldhari community came to the state of Maharashtra in Western India from Gujarat during the drought of 1972. Distinct from other pastoralist groups, the Maldharis are recognised by their colourful turbans, jewellery and clothes; but like other herders, they do not figure in village records or national censuses, and their economic contribution to GDP remains unrecognised. Unnoticed within the vast hidden economy of India, the Maldharis do not actively seek the help of the state to keep them and their animals alive during drought years, but instead use strategies skilfully built into their production systems to optimally use the variable resources of the drylands.

The relationship that the Maldharis enter into with sugarcane farmers and sugar-crushing factories differs from district to district. In some they purchase sugar cane, and in others farmers exchange sugar cane for dung. Some Gir herders have negotiated contracts with sugar cane factories whereby they are allowed access to sugar cane tops and fodder in exchange for the men working in the factory for a few hours everyday. Similar negotiations are also entered into for camping sites and the use of water.

Case study

Sugar cane, popcorn and sweets: integration strategies of Maldhari pastoralists in India[72]

Since their arrival in the State of Maharashtra, the Maldharis have integrated with the landscape, built up relationships, learnt new languages and adapted to the local conditions.

The main production strategy of the Maldharis is mobility to access discontinuous resources – periodically moving their Gir cattle, their entire family, and their belongings – but it is a strategy that is closely integrated with crop production. In the drier parts of the state they camp on fallow lands and open fields close to river banks in order to access sugar cane residue – the cash crop that has changed the face of semi arid Maharashtra, and which uses 75 per cent of the state's irrigation. During the monsoon months from June to September, the Maldharis graze their animals on the open fields and uncultivated open lands; but in the winter months from October to February they cut a deal with sugar cane farmers for sugar cane tops and other residue. The herds will also help out farmers with other crops – cereals, pulses and cotton – cleaning their land of stubble after harvesting and fertilising the fields with dung and urine.

An important aspect of the Maldhari production system is their use of resources that would otherwise be considered 'waste' (eg failed crops and crop residues), as well as fallow land and land that is considered barren or unproductive by crop farmers. They also make use of waste from factories, including the popcorn factory in Pune district: Here they feed their animals the corn culms after the corn is removed, and effectively recycle 'waste' into useful products for human consumption including milk. Their focus on accessing unused resources also extends to water sources; sometimes camping where there is a leak in a pipeline and quenching the thirst of their animals with the water being wasted. As crops change, farming practices change and farms themselves change hands, the Maldharis have had to undertake new negotiations and explore new options. In Ahmednagar and Beed districts, where the sugar cane factories have closed, the Maldharis have had to move on to new areas.

The main products from the Maldhari production system are milk, manure and calves. Milk is sold as raw milk as well as ghee, and sometimes as reduced/condensed milk. Milk brings daily cash into the household, whilst manure is sold every fortnight. Of the total daily milk produced by the herd, about half is sold to households near the camping site, a little less than half to milk and sweet shop vendors, and a relatively small portion – about 2–3 litres of the total produced – is kept at home for consumption. When sold to dairies the price of milk is determined by the fat percentage. As this varies across the lactation cycle, and dairy cooperatives also offer fairly low prices, many Maldharis prefer selling their milk to sweet shops, which use it to make sweets that are very popular in India with tea. Dairy cooperatives do not pay everyday, while sweet shops do. Milk is condensed to the solid popularly called khoya in India (also mawa or khawa), which keeps longer than fresh milk. The price is fixed depending on the quantity of khoya obtained from a litre of milk. In some areas their milk is bought at higher prices, the premium from being produced by an indigenous cow.

Preparation of khoya. Commercialization of dairy products opens up new income opportunities for those households with a milk surplus, but can also close down avenues of food security support for those without.

“My sweet shop is a huge success as it helps me sell the products I make directly. I would encourage my fellow Maldharis to also join my venture. With a little additional knowledge on livestock care nothing can stop us from being extremely successful.“

Hari Mitharam Bharwad

Integration – one, the other, and both

The integration of crop cultivation and livestock keeping at the scale of the farm – the sedentary mixed-farming of the European tradition with livestock kept on the farm all year round – is often impracticable or unsustainable in the drylands. This is due to a combination of factors including soil conditions, labour availability and agro-climatic conditions. Farm level integration in drylands areas may involve loss of necessary specialisation, higher risk of overgrazing due the high concentration of livestock, higher risk of conflict due to livestock trespassing on fields during cultivation, and increased competition for resources as everybody everywhere needs the same resources at the same time.

The history of rural agricultural development has been dominated by a focus at the scale of the farm, but dryland agriculture is more effective in managing variability to create advantages (more resilience) by integrating crop farming and livestock keeping strategies at regional and inter-regional scales, and in so doing there is less need to compromise on specialisation. Even in so called 'agro-pastoral' conditions, members of the same family will follow different paths of specialisation that cross only discontinuously at certain times of the year: often, one brother specialises in crop farming and another in livestock keeping.

Some analysts have now proposed abandoning the convention of addressing crop-farming and pastoralism as discrete production systems, as neither specialisation can really be found anywhere in the drylands operating independently from one another. Instead, there is a focus on their relationships within a 'mixed-systems' approach to dryland agriculture – ie seeing crop farming and pastoralism as complementary strategies in a variety of patterns of regional and interregional integration.[73] This perspective is consistent with the 'non-equilibrium' understanding of the drylands, and most helpful, but should also be adopted with caution. The traditional predominance given to crop farming and farm-level integration in the theories of change at work in agricultural development, is likely to require considerable long-term effort to prevent this innovative mixed-systems approach from slipping back into the traditional mixed-farming tunnel vision.

The integration of crop-farming and livestock-keeping strategies is often represented as occurring along a trajectory of evolution: at the end of the trajectory is the model of integration inspired by the European experience. But there is a fundamental misunderstanding in this representation, triggered by the habit of thinking in terms of discrete 'parts' rather than relationships. There is no 'correct' or 'complete' form of crop-livestock integration. What matters in mixed systems, at least in the drylands, is not what they are but what they do, and how integration in whatever form contributes to managing variability. Drylands variability is managed by opening up options, interfacing it with variability in the means of producing, and thus increasing adaptability and resilience.

For dryland agriculture, the added value of integration is in the possibility of being more than just one thing – the option of operating as one system or the other or both. Representing integration as a third system, once more just one thing, misses the point; it is like only being able to represent a business 'partnership' as a fusion.

Bambara millet farmers dig wells on their land to encourage pastoralists to leave their herds overnight.

Case study

Manuring contracts in Dlonguebougou, Mali[74]

Farmers across the Sahel are keen to get their fields manured. Even where chemical fertiliser is available it is both expensive and distrusted, as it can 'burn' the crop in years of low rainfall. Some farmers own their own cattle, sheep and goats, but many others do not have a large enough herd to keep their soils in good health and must negotiate deals with livestock owners.

In the village of Dlonguebougou in central Mali, agreements based on the exchange of water for manure have long been at the heart of relations between herders and farmers. Bambara millet farmers dig wells on their land and bargain for access to the well with visiting Fulani and Maure pastoralists. The herder gets sole use of the well and pledges to kraal their livestock overnight on the farmer's plots. Well-owners check up on the herd's movements, as many herders prefer to take their animals out to graze in the cool of the night, breaking their manuring agreement.

The significance of manuring contracts has shifted over time, depending on resource availability and options available to farmers and herders. The number of wells dug on Dlonguebougou's village lands grew from 12 in 1980 to 46 in 1992, bringing such a huge increase in the number of livestock visiting the village in the long dry season that pasture became very scarce: Some well-owners then sought cash, or access to a plough ox, rather than dung, in exchange for the sole use of the well. This suited herd owners who would prefer to keep their animals out at pasture, sometimes for 2–3 days in a row, and thereby accessing more distant grazing. In the last 15 years, very few new wells have been dug because they have been drying up early in the season. While the villagers attribute this to low rainfall, there may also be some draw down from neighbouring wells due to the large number in a relatively confined space. A few well-owners have invested in extra digging of their wells to reach further depths and increase water supply, an advantage which brings more assured water supply.

A large group of Maures, who for many years had brought their enormous sheep and goat flocks for six months of the dry season onto Dlonguebougou's lands, now no longer come. This is because they have managed to secure land further north on which to dig their own wells, settle and farm; and they want to keep their animals' dung to boost their own crops. The consequence of reduced water supply in the wells, and changed patterns of herd management, was not enough dung available in Dlonguebougou to keep the fields well manured. In October 2006 the harvest of the village fields was underway, but many fields were pink with striga – the parasitic weed that springs up on poorly fertilised land. All the farmers acknowledged this was a problem for them, and a direct result of there not being enough dung to manure their fields properly.

Fortunately, in the dry season of 2011, an exceptionally large number of visiting herders arrived in Dlonguebougou to gain access to water and grazing because a neighbouring commune had slapped a tax on transhumant herds pasturing in their zone. Many herds then began bypassing the commune in favour of villages like Dlonguebougou further to the south. In 2014, villagers reported that none of the wells had dried up, and they could water all the herds with ease.

Pastoralists at Haro Bake livestock market, Yabello, Ethiopia

Harnessing variability through markets

Increased access to markets during the 20th century has given dryland producers new opportunities for embedding further variability into their production systems. Markets make it easier to exchange livestock with cereals and vice versa, or unproductive animals (males, or females that have stopped reproducing) with productive ones – for example selling a bull and buying two heifers. Livestock can also be turned into cash in order to bypass a possible peak of mortality – for example, selling weak animals before the harsh time at the beginning of the rainy season, or in the early stages of a drought. Although through access to markets producers can embed new dimensions of variability, this can also bring along forms of variability that are outside the producers' control. This is not only in the form of price volatility, but also indirectly, as a consequence of replacing many dimensions of variability with one, therefore increasing the possibility that everything might go wrong at once.

The principle of using the market for destocking and restocking before and after a drought works in production systems where animals of the same breed are substantially interchangeable, but this assumption of uniformity within the system clashes with the logic of embedding variability in the herd. Pastoral livestock need to be capable of complex forms of engagement with their environment. Trained in functioning over a particular territory within a particular herd, animals in the pastoral systems cannot easily be replaced through the market, especially in large numbers. Like any team, a well-built herd or flock is a lot more than a sum of units. Livestock keepers made this point to the UK government during the foot and mouth epidemic, when offered compensation for culling their entire herds.

Current banking services are still largely inadequate to make the destocking-restocking process smooth and efficient for mobile herders (although the introduction of phone-banking represents a major advancement). Livestock traders in northern Kenya devised their own cash transfer system (the Burij system) to bypass the rigidity and costs of formal services: 'In short, informal cash transfer are fast, free, fair and flexible […] The key […] is trust and the relationships between the people engaged in the transfer […] mostly members of the same ethnic group or close friends'.[75]

Whilst increased opportunities in the market for labour should, in principle, introduce new options for moving in and out of dryland food production systems by increasing flexibility in labour management; in practice, this works only up to a point: finding a job outside the system is a lengthy, difficult and risky process, and comes with high transaction costs – especially for people who live in remote areas.

The drive to land titling has created another new market, and a new generation of pastoralists and farmers who now lease out pasture and water.[76] While this has opened up some new options, it has also contributed to introducing permanent forms of inequality. Above all, market-mediated access to these resources has proved not nearly as flexible and fast enough to effectively interface drylands variability. In China, the fragmentation of the rangelands that followed government-driven processes of privatisation is now being spontaneously corrected by the producers organising themselves into cooperatives.

Fences being removed in Inner Mongolia after the cooperatives were established. Through the re-aggregation of rangelands, cooperative members can access larger rangeland areas. Manglai Gacha Cooperative has around 170,000 mu (28,000 acres) of rangeland providing a larger space for movement to cope with climatic variability. By being a cooperative they also get support during disasters from other cooperative leaders and government. For instance, in 2010 Manglai Gacha was struck by severe snow blocking their transhumance trail to the south: Through the Animal Husbandry Bureau, government helped to clean up the snow on the trail – support that would be impossible to get by individual herders alone.

My younger brother and I have 500 to 600 sheep and 11,000mu rangeland. The other households each have around the same, so together we have 50,000mu of rangeland and we herd our sheep together. We create herds according to age and type. I manage the lambs, which will be sold this year. My younger brother herds the ewes. Hasichaolu herds the two-year old sheep, which will be sold in the autumn. Haobisihalatu herds the breeding rams. Siqinbateer herds the yearlings, which will not be sold this year. These arrangements are flexible; you can herd whichever you like. We use the rangeland together and don't need to pay for using each other's rangelands. When drought occurs, we move to other cooperative members' rangelands for a period. We needn't pay. The receiving households always agree: If they don't accept such arrangement, they wouldn't have joined the cooperative. If I plan to move to their rangeland, I call them today and tomorrow I go. I have never been rejected. The biggest benefit of herding together is to protect rangeland. It requires less labour. The sheep and cattle gain more weight because they can graze on a larger rangeland and graze different types of forage. Then we get a better price.

Wuhulege
aged 40, Harigaobi Gacha cooperative.

The success of community rangeland governance in Inner Mongolia can be attributed to the effective application of indigenous knowledge, designing the institution based on the functional strategy of pastoralism, and using seasonal mobility to achieve flexible use of heterogeneous rangeland resources at landscape scale. Cooperatives also reduce production cost through sharing labour and the collective purchasing of production materials and services.

Case study

Using landscape level variability for innovative rangeland governance in China[77]

China's total rangeland area is around 400 million ha, of which 40 per cent are in the arid and semi-arid steppe of China's north and northwest, and 36.4 per cent in the Qinghai-Tibet alpine region, which includes meadows and swamps as well as steppe. The 159.95 million hectares of arid and semi-arid steppe includes Inner Mongolia, Xinjiang and other 8 provinces. Annual precipitation varies from 550mm to below 50mm from east to west, with a long 'cold season' and often extremely hot 'warm season'.[78] A drier and warmer climatic trend is now bringing increasing incidents of drought and snow disasters.[79]

Like elsewhere, pastoralists in China had always used mobility strategies and community level management to manage natural fluctuations in grazing resources. But at government level pastoralism has been viewed as a backward mode of production, preferring instead to promote intensive animal husbandry through a series of policies to encourage herders to settle down, build livestock shelters, drill wells, plant forage and improve livestock breeds.

Thirty years ago China applied the Rangeland Household Contract Policy (RHCP), expecting to improve protection and 'rational use' of rangeland by stimulating individual motivation. The consequence of contracting to households was rangeland fragmentation, degradation and a reduction in individual herders' ability to cope with natural disasters. The flaw in the policy was that RHCP failed to recognize the heterogeneity of rangeland resources. It assumed rangelands are equalled to fodder, and by directly allocating the resources (land) to individuals it separated the functional connection between livestock and heterogeneous resources.[80] With rangeland contracted to individual households, the pasture area that each household could use remained small and fixed – making them unable to meet the intake needs of their livestock herds.[81]

In an approach that reverts back to community-based understanding and use of landscape discontinuity, a number of locally based cooperatives in Inner Mongolia are now creating new governance structures for the rangelands. Cooperatives (through re-aggregated individually contracted rangelands) are helping re-establish the connection between livestock and resources. The pooling of pastures, livestock and labour supply among households, based on traditional reciprocal norms, is helping to recover livestock mobility and promote more effective engagement of poorer herder with the market. Higher mobility, and fewer separated herds, enables more effective use of resources. And more importantly, the improvement of forage production increases the quality of livestock and stabilises cash income.

In some areas in the Qinghai-Tibetan area pastoralists kept collective tenure but have established a grazing quota system (non-tradable) to better adapt to the changing demographic and economic conditions. Experiential indigenous ecological knowledge of rangeland conditions, and likely annual weather conditions, are used to set a quota of livestock for each village member. The household head takes a cultural vow not to cheat on their livestock numbers; and rich families (with excessive livestock) loan out their younger livestock at an agreed price to poorer families whose livestock is less than their quota, without interest being charged. This system has helped improve rangeland productivity and livestock conditions, and led to more equal access to rangeland among villagers.

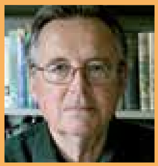
Dryland producers harness variability for food production

Farmers and herders understand the environmental variability of the drylands, and connect with its variability using production strategies that respond to opportunities as they arise. For example herders use mobility strategies to access the nutrients in fodder as they peak at different times and different places across rangelands; whilst farmers use diversification strategies to plant different crops at different times in different places in line with variation in rainfall and soil moisture conditions.

There is no one 'best' production strategy in the drylands: producers need to be skilled at keeping a 'portfolio' of livestock or crops that can respond quickly to changes in conditions, combining, adjusting and diversifying as the uncertainty of the climatic conditions unfolds. Rather than avoiding risk, dryland producers embrace it; and in this way can obtain higher levels of productivity than would be anticipated based on the available resources. They can stretch the length of the growing period in terms of both crops and pasture – harvesting discontinuous water sources, tempting their herds onto the best grazing, and negotiating access to either far-flung areas or local crop residues.

Dryland agriculture is highly adaptive, as seen through the huge variety and scale of production strategies that integrate crop farming with livestock. Discontinuous and large-scale forms of integration allow flexibility in labour supply at key times, or the sharing of water sources, manure, or surplus milk. Integration works through systems of negotiation and reciprocity that constantly change in line with the constantly changing dryland resources.

"Key strategies for herders and farmers are built around rapid reaction to the high variability of dryland environments. Farmers diversify into a range of alternative activities; herders specialise and focus on the search for high value nutrients in the vegetation. For both, the ability to move fast and sometimes far is critical to their response."



Jeremy Swift
Student of pastoralism in Africa, the Middle East and Central Asia.

Livestock kept in pastoralist systems retain behavioural patterns that are typical for wild populations. The buffalo breed kept by the Van Gujjars in the Himalayan foothills will become restless and start moving towards their summer or winter grazing areas. The Van Gujjars take the cue from their animals and follow them.

Part 3

Drylands variability as a structural difference

"Scarcity with good governance is better than abundance with no governance."

Hassan Galgalo Luma
(Boran elder, Isiolo, Kenya)

Would you describe an artificial limb as a coping strategy? It depends on the limb. For centuries artificial limbs have been imagined as lesser substitutes of missing limbs, and designed as such. Caught in this self-fulfilling prophecy, the poor functionality of the resulting objects only confirmed the initial assumption. This was until someone approached the design of artificial limbs from a fundamentally different angle and invented the J-shaped 'blades' that did not try to imitate legs but finally worked instead of legs.

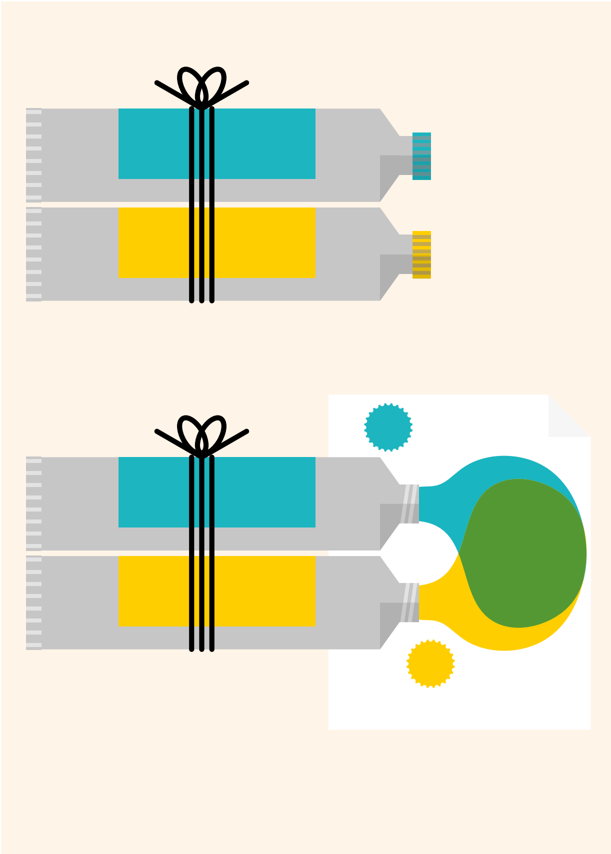
Some would argue it was just a case of brilliant design: one of those moments like the shift from wing-flapping machines (that imitated birds but could not fly) to airplanes. But why would something so much simpler take so much longer to invent? We could speculate that, before the J-shaped prosthesis could be imagined, a change of mind-set was necessary, from seeing the absence of limbs as a structural limitation to seeing it as a structural difference. The rest is history. Famously, at the 2012 Paralympic games in London, Oscar Pistorius, double amputee, took just over 45 seconds to run 400m on 'J-shaped' carbon-fibre artificial limbs. Pistorius' attempts to enter 'able-bodied' competitions were long rejected on the basis that his artificial limbs gave 'an unfair advantage'.[82]

Drylands variability is a structural difference that has traditionally been seen as a structural limitation. In this case, the fundamental change in mind-set is still on going. We are mostly still locked into imagining wooden legs and wing-flapping machines. Seeing drylands variability as a structural difference still needs to happen.

We are still locked into mind-sets that see drylands variability as a limitation.

Gabra pastoralist children on their way to school

Formal education is one area of intervention that urgently needs to be provided in a format capable of interfacing the structural variability in dryland conditions. In Kenya, continuity of teaching is regularly disrupted in the drylands as a result of under-funding and late release of approved funds; the unwillingness of the government to make special budgetary provision for nomadic education; indiscriminate transfer of teachers from nomadic primary schools to conventional primary schools without replacements; absenteeism (arising out of staff morbidity or the need to travel long distances to the nearest education office or town for services); inadequate or non-availability of teaching materials; collapse of infrastructure; droughts; the dearth of teachers in terms of quantity and quality; and insecurity. In view of these disadvantages, learners in the drylands need to be provided with alternative platforms for curriculum delivery that are different from the typical school and reflect structural variability. Flexibility in approach with initiatives such as 'mobile schools', Open and Distance Learning (ODL), and application and use of varied ICT's will be necessary.[83]



What matters in a holistic approach is not the inclusion of all the parts of a system, no matter how comprehensive, but the fact that they relate to each other.

Holistic versus sectoral

All school children know that mixing a unit of yellow with one of blue gives two units of green: something that is neither yellow nor blue (see figure opposite). That the 'whole' can be different from the sum of its parts, and usually is so, is also the idea behind the notion of 'systemic' or 'holistic'. Today, most development policies and programmes emphasise the importance of a 'holistic' or integrated approach. Unfortunately, this is often understood as simply referring to an all-inclusive perspective, and thus 'integrated' programmes try to include a large portfolio of activities from health to water development, natural resource management, agricultural extension, and marketing.

What matters in a holistic approach is not the inclusion of all the parts of a system, no matter how comprehensive, but the fact that they relate to each other. What matters, is the emphasis on the relationships; the understanding that it is such relationships that define the 'parts' of a system, and no 'part' exists or can be correctly analysed if separated from the relationships that define it. A programme that focussed on only one area of intervention could qualify as holistic if such an area was understood by its relationships with the relevant context. A programme that combined a large diversified portfolio of activities covering all possible sectors of intervention, but which still understood each of them as a discrete set of problems and solutions, would remain sectoral.

There is nothing intrinsically wrong with not being holistic. On the contrary, the rationalisation of unmanageably large and heterogeneous sets of problems into smaller and more uniform sets remains the most efficient approach in many contexts. But it is not an appropriate approach in contexts that are dominated by variability. Where variability is structural, problems come in dynamic correlations and it is impossible to disentangle causes from effects. An approach that reduces these contexts to sets of discrete problems will miss out the correlations. It is the correlations that matter most – and by ignoring how problems correlate, the risks this involves are effectively concealed, therefore increasing the danger.

For example, by understanding the system 'car-skidding-at-70-miles-an-hour' as two discrete problems – 'high speed' and 'wrong direction' – the dynamic correlation between speed and direction is concealed, leading to two discrete solutions: 'lower the speed' (ie braking) and 'correct the direction' (ie turning the wheel). End result not good. If on the other hand, the dynamic correlation is acknowledged and understood, and followed up by making the car continue straight ahead through accelerating, the problem is managed to everyone's advantage.

A similar difficulty is found in the use of the concept 'social-ecological system', which has become relatively popular in development circles along with the boom of interest in resilience thinking. The concept of social-ecological system was introduced in order to emphasise the circular causality between 'social' and 'ecological', and consequently that any separation is arbitrary.[84] The original emphasis on dynamic correlations has easily gotten lost however, and complex contexts like the drylands are often introduced as social-ecological systems only to proceed with a traditional analysis of the 'social' and the 'ecological' as discrete dimensions.

Pastoralists living near Lake Turkana engage in daily fishing as part of diversification in their livelihood strategy. The construction of a series of dams in southern Ethiopia is likely to lead to a fisheries collapse.

"We do not yet know the cost benefit analysis of irrigation, however considering that pastoralism has been the best production system for centuries in our land, we are certain that the same investment in pastoralism would bring more benefits to the people and the environment than irrigation."

Ali Wario
MP for Bura

Case study

Consequences of sectoral development: Ethiopia's Omo Basin and Lake Turkana[85]

Ethiopia's Omo-Gibe River rises in its high rainfall area in the highlands, falls to the country's semi-arid lowlands and then terminates in Lake Turkana in Kenya within an extremely arid zone. Lake Turkana is Kenya's largest lake, whose semi-saline water is dependent on the Omo floodwater to bring nutrients and stimulate fish breeding. The perennial Omo-Gibe River has always provided water for people, livestock, wildlife and flood recession agriculture. When it floods it overtops its banks, the floodwaters rejuvenate the plains and indirectly recharge the aquifers beneath. As the floodwaters recede, cultivation can take place – the hydrological discontinuity of this drylands river playing an essential role in ecological and livelihood diversity.

In the Lower Omo, the Government of Ethiopia's target is to manage the river's natural hydrological discontinuities through engineering predictable uniform hydrological cycles. Ignoring its huge downstream value to agro-pastoral and fishing communities, and ecotourism, construction began on the Gibe III hydropower dam in 2006, 600km upstream from where the river discharges through its delta into Lake Turkana. Gibe III is the tallest dam in Africa, with an electricity output for Ethiopia that will exceed Kenya's total generating capacity. It will capture and store the discontinuous variable water flows in a reservoir 150km long, with a volume of 15 billion cubic metres, arresting the passage of river borne sediments and nutrients. When operational, the reservoir will release water back to the river through turbine shafts and spillways, altering forever the natural hydrological cycles and levelling the peak flow periods. Two further dams, Gibe IV and V, are also being planned. The river flows will ultimately be entirely regulated.

Once completed the Omo River's cascade of dams will create higher dry season water flows, thereby sustaining large-scale irrigated agriculture downstream of the dams throughout the year. Irrigation infrastructure is being built to exploit this potential, with large areas of land excised from the Omo and Mago National Parks by the Ethiopia Sugar Development Corporation. The level of Lake Turkana will fall during the three years it will take to fill the Gibe III reservoir. The hydropower station will regulate the natural hydrological variability, and the lake will fall by up to 20 metres with the planned irrigation abstractions, probably leading to a fisheries collapse. For local people who have long practised traditional flood recession agriculture along the Omo's riverbanks, the loss of the floodwaters will be disastrous. People will be displaced, pastures will no longer be replenished, and with commercial irrigation occupying the riverbanks, pastoralists will also lose their major resource access.

Rather than destroy a diverse ecological system through development, it is preferable to design development that sustains the ecological system. The Omo River and Lake Turkana are flood-pulse ecosystems. They have developed with natural variable hydrology, including floods that flush river channels, and that rejuvenate adjoining landscapes through seasonal inundation, and that collect, convey and distribute nutrients. If the variable hydrology is substituted by the uniformity proposed, the system's diversity and resilience will be destroyed.

Case study

The Turkwel irrigation scheme[86]

The Turkwel irrigation scheme in NW Kenya is an example of a risk aversion strategy that was created in the 1960s to help lift dryland households out of poverty. The management strategy chosen – irrigation of the seasonal river for crop production – sought control of the drylands environment, rather than helping the pastoralist Turkana to work with drylands climatic variability. The irrigation scheme proved unsustainable and collapsed when donor funding ended in the 1990s.

In 2003 the National Irrigation Board restarted the Turkwel irrigation scheme; but declining yields, poor soils and increasing salinity have continued to plague the programme. Today the pastoralists are still poor, possibly poorer, and have fewer options than previously.

Most are now ageing farmers unable to sustain a harvest, trying to support a younger generation who are not interested in farming. Despite decades of sedentarisation literacy rates remain low. Today's irrigation scheme is mirroring that of the 1960s – suffering from serious water shortages as well as being top-down, bureaucratic, externally imposed, techno-centric and non-participatory.

"Drought is not disaster. It is predictable hazard, it only becomes a disaster or emergency if it is not planned and managed well. We need to better plan in ASALs and effectively manage droughts. If we can do this, we can end drought negative impact on the people and livelihoods."

Hon. Francis Chachu Ganya

Risk taking versus risk aversion

Context

- discontinuity
- variability
- uncertainty
- risk

(CC: weather volatility)

Conventional strategy: aversion

- risk reduction
- introducing stability and uniformity
- increased planning

(command and control)

Adaptive dryland strategy: management

- working with discontinuity
- managing risk rather than avoiding it
- embedding discontinuity in the production system
- real-time management
- flexibility and responsiveness

Risk taking versus risk aversion

Dryland agriculture is commonly considered a risky enterprise. As people who specialise in a risky enterprise, small producers in rainfed farming and pastoralism are to be understood as risk-taking entrepreneurs. In the wider economy, risk-taking by entrepreneurs is supported as the backbone of modern capitalism (a value captured in the old saying 'he who risks nothing gains nothing'). Support to entrepreneurs is provided not by promoting risk aversion but by reducing the danger of taking risk. Typical examples are bankruptcy laws and institutions like limited liability (started during economic liberalism in 19th century Britain), including power for courts to impose on creditors permanent reductions in debts. The reason behind these measures is the realisation that lack of a second chance discourages risk-taking by entrepreneurs, at a cost to the economy as a whole.

Risk aversion and reducing the danger associated with taking risk are strategies that may go in opposite directions (see figure opposite). Where variability is structural, the better one is at managing risk, the more risk one can take, and the higher the returns. Professional warfare is an obvious example of a context dominated by variability. Apparently, the motto 'who dares wins', which is clearly more about managing risk than reducing it, is used by twelve special force units around the world.[87] Similarly, a good climber manages risk; one who does not go climbing, reduces it. In air-traffic control (an example of 'high-reliability system'[88]) improving risk management means being able to keep more planes in the air (ie more absolute risk) without increasing the occurrence of accidents. Risk aversion (aiming at reducing absolute risk) would mean trying to keep as many planes as possible on the ground: no risk, but no business either.

Risk management is often confused with risk reduction and finding ways of 'coping'. In water, people who cannot swim try to cope by stretching themselves as vertical as they can, looking for support under their feet (an aversion strategy: reducing the risk from losing one's footing and going under with nose and mouth). Swimming, on the other hand, that is managing the risk of being in water, requires a horizontal position, that is getting your feet further away from the probability of finding your footing, and instead of relating to water as a threat using it as support. Introducing a risk aversion strategy where risk cannot be averted (because it is structural) is like 'helping' a swimmer to keep a vertical position.

This is a common approach to risk 'management' in drylands development in all the cases where there is no clear distinction between risk aversion and risk taking strategies, and risk management is confused with risk aversion (or minimising risk). It leads to a failure in distinguishing between vulnerability associated with risk-taking or risk management, which could be described as strategic vulnerability, and unwanted vulnerability, associated with the obstacles to the exercise of risk management (sometimes linked with the ordering/stabilising processes for risk reduction).

The Raika shepherds from the Godwar area in south-central Rajasthan make strategic use of all available biomass in order to produce meat for the market, organic fertilizer for farmers, and milk for home consumption and sale. The shepherds make the best use of what is already available – finding feed resources in harvested fields, forests and from common property resources such as revenue land and village grazing grounds. The Raika specialise in niche utilisation, making use of what otherwise would be wasted. For security purposes and mutual support, Raika families organise themselves into herding groups of 8–15 families that together are called a dera and who are led by a patel. A dera may contain around 3–4,000 sheep. The patel is elected every year based on his experience, his contacts and impartiality in decisions on when and where to move, and his skills at liaising with landowners or authorities. Individual family units in the dera are called dolri – the dolri being the 'charpoy' (string bed) on which the possessions of the family are stacked (bedding, cooking utensils, supplies). The dolris are set up in a wide circle in the same position to each other in every encampment. The sheep are kept within the circle at night.

At the end of the rainy season in October, the sheep of the Raika become restless and indicate their desire to start moving – shepherds having to actively stop them from going on migration on their own. With the crops still standing, farmers are often not welcoming to the shepherds, but by the start of the hot season in mid March the crops have been harvested and it is the best and the easiest time of the year for the shepherds. Neither sheep nor shepherds have problems coping with the heat. The lambs are gradually sold off and milk is sold to teashops and private customers. In July when the first clouds suggest rain is in the air, the sheep indicate that they want to return back home.

"When the rains start, then the animals march very fast back home, about 20 kms per day."

Nagaram Raika (patel)

Case study

Highly productive risk takers – The Raika shepherds of Godwar Rajasthan, India[89]

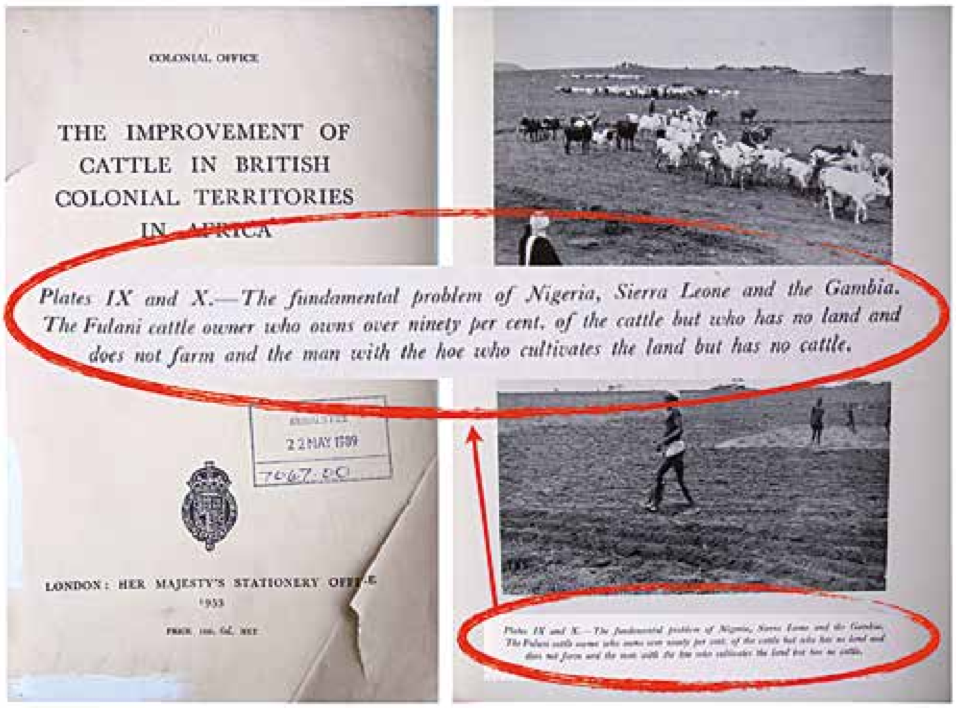
India is the largest exporter of sheep and goat meat worldwide, amounting to 22,608 MT and valued at almost 7 billion rupees in 2013–2014. The vast majority are raised in drylands in extensive pastoralist systems. In the Godwar area of south-central Rajasthan highly professional sheep rearers are organised in large groups that fan out across Rajasthan and into adjoining states – including Punjab, Haryana, Madhya Pradesh and Gujarat[90] – to systematically utilise crop aftermath and biomass from common property resources (CPR). Grazing CPRs is a response to the structural unpredictability of the eco-system where rainfall fluctuates from year to year, whilst grazing crop residues is a dynamic solution responding to variable resource availability. The specialized sheep-rearing communities – including the Raika, Rajputs, Sindhi Muslims, Gairi, and Gujjar – undertake long distance migratory systems for eight to nine months of the year, producing meat for the international market, organic fertilizer for local farmers and milk for home consumption and sale.

The Raika move distances of between 150 and 400km from their home villages in Marwar to their summer grazing grounds. The destination depends on the knowledge of the patel (group leader) and his collaborative relationships with farmers.[91] It is a continuous process of scouting for new grazing opportunities, and also of avoiding competition and conflict. The sheep pastoral system is intricately integrated with crop cultivation, dependent on farmers providing access to their fields and on remunerating the shepherds with grain, tea, sugar and sometimes cash. The sheep graze on the aftermath of wheat, jowar, soya beans, tur, masoor, channa, maize, groundnut, fenugreek, mustard, as well as various medicinal plants. The cultivation of soya beans has increased in recent years and provides excellent nutrition for sheep, which search out the residual beans, to the extent that a new 'soya bean route' has been carved out. Whilst fifty years ago there was little irrigation and the cropland was fallow for nine months of the dry season, the establishment of tubewells has led to year-round cultivation and has removed this fallow. New opportunities open up, however, as crop cycles change and as groundwater resources are depleted and people return to rain-fed farming.

Based on a total sheep population of Rajasthan of around 9 million head, at least two million ram lambs are produced and sold each year by the pastoralist sheep rearers. Calculating an average live weight of 11kg per lamb, this would translate into 22 million kg.[92] Buyers actively seek out these lambs by following the Raika on their migration and coming to their villages during the rainy season. But not everyone is willing to pay for the sheep. The Raika face considerable threats from sheep theft: teams of two on a motorbike, one driving and the other grabbing a sheep, do most of the stealing. The Raika also talk of gangs of 20–30 men wearing black clothing and driving up at night in pick-up trucks. Thefts are particularly common while driving the sheep along highways, when flocks are on their own with a single herder, or when drinking at ponds. Loss of fallow land through agricultural intensification, as well as expansion of built up areas and highways, creates further risk. Despite their overall value to the state in terms of live weight of meat, milk and manure, the police rarely investigate the theft of their property.

"The government knows very well about our problems, but it does not do anything. We can only reach the low level officials. We can't get the attention of Modi-ji."

Hinduram from Ghanerao



For the best part of the history of agricultural development, forms of integration have gone unnoticed. Operating with a notion of integration locked onto the 'mixed farming' model, policies and programmes promoting crop-livestock integration as a way of increasing the efficiency of the agricultural sector were, in most cases, unable to recognise it when they met it.

'All sources of livestock data and statistics – such as agricultural censuses, livestock censuses, periodical and ad hoc agricultural sample surveys, household income or expenditure surveys – rarely if ever generate comprehensive information on pastoral production systems'[93]

International concern for the productivity of the Sahelian rangelands started in the late 1960s. From 1976 to 1980, the Centre for Agrobiological Research at Wageningen, Netherlands, coordinated a major research programme in Mali. The scientists concluded that: 'Replacing nomadism and transhumance by sedentarism will have a very negative effect on animal productivity'.[94]

Looking without seeing

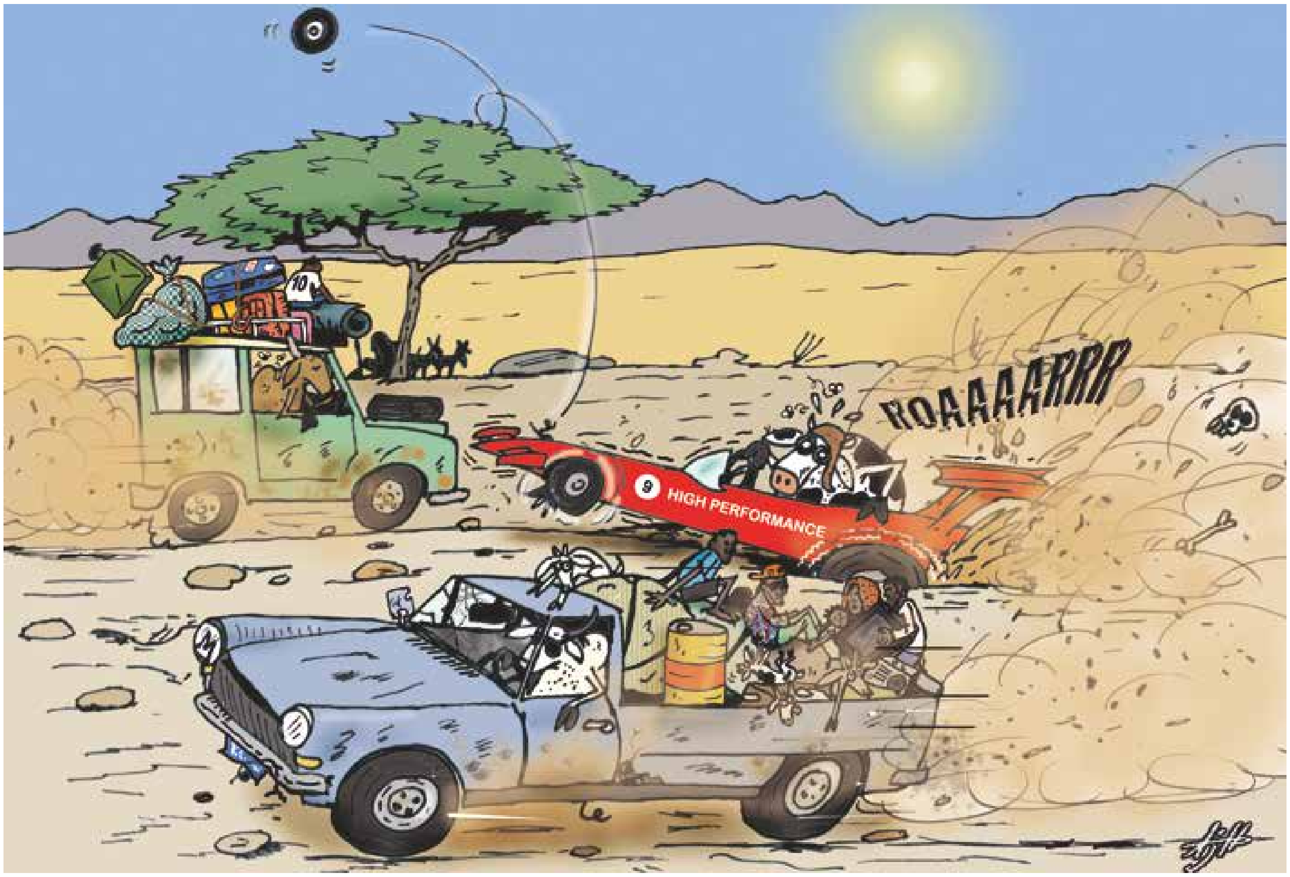
What is the best bird or the best fish, or the best tree? Even answering about the best mammal would be difficult, if we didn't happen to be naturally a bit biased. Natural selection is obviously not a race for the best. Biological processes produce diversity and thrive on it. The result is an intricate multitude of moving paths for virtually everything: different ways of seeing, hearing, moving, extracting and processing energy, reproducing…even different forms of intelligence.[95] Agricultural development, on the other hand, has so far shown a tendency to operate with a single-path approach. In many cases this has resulted in people looking at the local context but not seeing that the 'solutions' development wanted to introduce were already in place, albeit in unexpected forms.

In the 1920s, the veterinarians operating in West Africa quickly became aware of the challenges of undertaking breed selection in the tropics, where structural variability concealed and confounded the results of the breeding efforts.[96] In order to increase livestock productivity, they therefore turned their attention to improving animal nutrition. This was in fact the strategy being followed by pastoralists, like the Wodaabe in Niger, who specialise in optimising herd nutrition through mobility and by fostering feeding selectivity in their animals. Coming from a European tradition, however, the veterinarians' notion of improving animal nutrition was locked onto the single-path 'fodder cultivation'. In Niger, they embarked on a long line of frustrating attempts to cultivate alfalfa, unable to see the solution under their eyes in the strategies of the Wodaabe.

The notion of intensifying small-scale agriculture in association with crop-livestock integration is another good example. The model is well known: specialised extensive crop-farming and livestock production systems are driven to integration at the farm level (mixed farming), through scarcity of land following demographic growth. In this case, the vision is locked onto the mixed-farming single-path, and has long got in the way of recognising the many actual forms of crop-livestock integration that exist not at the scale of the farm, that do not involve loss of specialisation, and that do not represent a closed system. Integration is seen at regional or even interregional scales, involves interaction between specialised grazers and farmers, and is discontinuous in time – ie is seasonal.[97] (See p.47 in this book).

Fortunately ecological science, and in particular resilience thinking, are now placing much more emphasis on the existence of multiple paths, including multiple states of equilibrium. A recent overview of systems of crop-livestock integration stresses the 'need to seek a new balance of attention towards the performance of whole farms and regions, away from attention to parts and individual yields'.[98]

The single-path approach, still common, exposes development to the risk of undermining existing and well-rehearsed forms of sustainable intensification in the drylands, while trying to introduce conventional intensification unfamiliar to local producers and untested in the local context. Besides, tying intensification to crop-livestock integration in the form of mixed farming makes it conditional on sedentarisation, in economic and environmental contexts where many existing paths to crop-livestock integration are highly dependent on mobility.



'Just as Formula 1 racing cars require a high quantity of specialized inputs to perform on specific tracks, so too do the small number of highly geared breeds that have been refined over the last four or five decades to satisfy the immediate needs of developed world […] However, in the developing world […] emphasis on further refining and fine tuning locally adapted indigenous breeds will result in more sustainable outcomes than utilising high-producing breeds […] improved in developed-world environments.'[99]

Assumptions on ‘productivity’, ‘production’ and ‘performance’

Some apparently obvious concepts that are commonly used in policy documents and everyday development debates have a technical meaning that is much narrower, sometimes to the point of being almost unrecognisable. In their general meaning they may appear innocuous or even desirable, but in their technical meaning (the meaning used in implementations) they can trigger forms of exclusion.

In animal production theory the fundamental concepts of production, performance and productivity imply conditions that are characteristic of input-intensive systems. ‘Production’ assumes the possibility of measuring a steady value under uniform conditions. ‘Performance’, assumes that time is a uniform succession of identical units (ie ignoring seasonal variability). While ‘productivity’ assumes a steady supply of feed (energy) input uniformly distributed throughout the year. The extension of these narrowly defined concepts beyond input-intensive systems, to contexts of production where their underlying assumptions are unmet, triggers an impression of shortcomings and ‘problematic’ conditions. Structural difference is thus ‘read’ as structural limitation.

In the drylands, as we have seen, conditions are rarely steady or uniform; and identical units of time can affect performance in hugely different ways depending on discontinuous variables. Feed supply is also not steady or uniformly distributed throughout the year, but rather is available in ephemeral concentrations; and its optimal exploitation depends on a range of variables (eg herding competence, the capacity for mobility, the animals’ ability to feed selectively). But as a consequence of the gap between underlying assumptions in technical concepts and actual reality of production in the drylands, carefully selected and highly adapted local breeds or species are often described as being unproductive or ‘low yield’.

If the motor industry ‘optimized’ their production and graded all categories of vehicles (economy, electric, station-wagons, luxury, sport, 4WD) based on Formula 1 performance on a racing circuit, it would look pretty absurd. Yet, this is exactly what happens with breed comparison when the productivity of local breeds is measured on the basis of a definition of ‘input’ that is normalised for input-intensive systems. Try to take your children to school in a Formula 1 car, keep it parked on the street, and use it to do your weekly shopping. When high-performance breeds are exposed to the variability in feed inputs that is characteristic of the drylands, their Formula 1 performance drops dramatically low compared with pastoral breeds on the same inputs, and can even be negative (ie the animal dies).

Until developing countries succeed in building suitable road networks, those who can afford it will continue to buy strong (and possibly luxury) 4WDs, rather than fast sport cars. Development projects on the other hand, often export the equivalent of fast sport cars – high-input breeds – even in the context of restocking interventions to the poor, who then cannot afford to maintain them.

Women weaving yak hair in China's Qinghai-Tibet alpine region.

'Some plant species in arid environments require regular grazing. Arid rangeland plants that are grazed continuously may have lower residual biomass and ground cover, but they may also have greater production and better survival than un-grazed plants. Consequently, grazing, rather than being destructive, is necessary for proper management of arid zone pastures'.[100]

"The rangeland was good in the first year of grazing ban, but it is growing worse with the increasing duration of grazing ban, the shrubs are dying. The dry grasses and dead branches cover-up the shrubs, and the shrubs cannot sprout and will gradually die. Reaumuria soongorica and Haloxylon ammodendron can re-grow the next year if they are grazed. However, if they are not grazed this year, they will not grow well next year. The pasture was green when the goats grazed it; now you can only see the grasses grown in previous years. They are brown. You can't see the green re-grown branches underneath. The old branches of Salsola passerina would cover-up the new branches. We used to cut green branches of Salsola passerina to feed lambs at this time of a year (before the grazing ban policy was implemented). However, when I went to see the rangeland a few days ago, the new shoots have not grown out yet."

66-year old woman from Buguta Gacha, Inner Mongolia

Still defining dryland environments as 'fragile'?

Development literature often characterises the arid and semi-arid lands with very variable rainfall patterns as fragile areas.[101] For example, the UNDP Global Drylands Imperative talks of 'managing fragile environments'.[102] A recent review of evidence on dryland pastoral systems and climate change, published by FAO, refers to the 'sustainable and adapted management of these fragile ecosystems'.[103] According to the organisers of the 11th International Conference on Dryland Development in held in 2013 in Beijing, 'Dry areas of the world have highly fragile ecosystems'.[104]

It is important to notice that, in these uses, 'fragility' is presented as a characteristic of the ecosystem: the claim is that drylands are fragile. It is important because ecologists have abandoned this view at least since the 1990s. Understanding fragility as a bio-physical characteristic of the environment is a 'memory effect'; in existence since the time when the 'equilibrium' model was still the main explanatory framework in ecology. In this view, 'fragility' is the reverse of stability and refers to a balance being prone to be disrupted; drylands fragility is deduced from its structural variability.

Following the redefinition of the boundaries of the equilibrium model in the 1970s, the use of the term 'fragility' in ecology has referred to human-environment interaction; that is a relationship rather than a characteristic of the ecosystem. According to a commonly cited definition in this new light: 'fragility implies a mismatch between human use and biophysical conditions.'[105] The difference introduced in this way is anything but semantic: under this definition, fragility is no longer a structural limitation but a circumstance, one that depends on a particular kind of management being used in relation to a particular kind of environment.

A central message of this book is that, in the new understanding of the drylands, it is the production strategy that determines whether variability is a problem or an asset. It is the same with fragility: 'a sloping, moderately watered, hillside with light- to medium-textured soils could be extremely 'fragile' under one use, but under another, based on better adapted technologies and management practices, could be quite productive, even over the long-term'.[106]

Fragility as a mismatch of human-use and biophysical conditions is logically associated with strategies that relate to drylands' structural variability as a problem. On the other hand, the production and livelihood strategies specialised to take advantage of drylands variability as an asset – small-scale crop-farming and mobile pastoralism, in their many pathways of integration – are associated with resilience.

Today, ecologists no longer consider instability and resilience as opposites, but talk of 'resilient drylands' while recognising variability as structural.[107] There is mounting evidence of resilience in dryland farming from a variety of case studies in Africa.[108] But the equilibrium 'memory effect' remains strong, and confusion is frequent even amongst analysts who have ceased to rely on the equilibrium model. Keeping the focus on fragility as a relationship, rather than slipping back into talking of 'fragile ecosystems' and 'fragile drylands', is critical.

The Kharai Camel is a unique eco-tonal breed that has adapted to the coastal and dryland ecosystem of Kachchh district of Gujarat and feeds on mangroves. Sahjeevan (a local NGO) and the Camel Breeders' Association, with the help of the Government of Gujarat and FAO, have initiated the registration and conservation of this unique breed. Progress has also been made in allowing camel milk to be marketed through reputed dairy brands. Initially camel milk was not officially recognised as being a product for human consumption, like cow or buffalo milk, but in recent months the Gujarat government has begun to consider the marketing of camel milk on a large scale. The Kharai camels swim 2–3kms in the coastal areas to access the mangroves. The herds stay to eat for two days and nights and then return back to drink non-salty water away from the coast. Rapid industrialization and construction along the Kachchh coastline has led to large-scale destruction of mangroves and is now obstructing the movement of the camels to their mangrove islands feeding areas along the coast.[109]

The Banni grasslands in the Kachchh district of Gujarat, India, are Asia's largest tropical grassland. The genetically distinct Banni buffalo, Kachchhi goat, Kachchhi camel and Kankrej cattle are all specifically adapted to the Banni grassland and its harsh climatic conditions. The Banni buffalo has the unique quality of being able to graze at night, and is an excellent milk producer – averaging 6,000 litres annually and an average daily yield of 18 litres. Through the formation of the Banni Breeders Association, a Maldhari pastoralist cooperative society, the buffalo has now been registered as a unique national breed at the national level. The cooperative has also ensured that the more than 250,000 litres of milk a day sold by the breeders to the dairy industry is now sold at the reasonable price of 40 to 50 Indian rupees – previously the milk used to fetch only around 15 to 19 rupees. Proud of their breed, the Maldharis of Banni argue you would need to sell two Nano cars to buy one Banni buffalo and 'after 10 years of use, a Nano car goes to the bhangarwala (waste metal collector) but a Banni buffalo will have produced at least four new buffaloes'.[110]

Comparing ecological efficiency – properly

Pastoral systems and small-scale dryland farming are included in national and global assessments of the ecological efficiency of food production systems – helping inform policy, investments in development and climate change mitigation. The standardisation of indicators and datasets used for assessments is therefore critical, but different ways of calculating the ecological efficiency of food production can return substantially different results depending on what variables are being measured.

Assuming uniformity in non-feed inputs.

To assess the ecological efficiency of livestock systems the rate of conversion of 'input' into 'output' by an animal's metabolism is used as a proxy. That is, the rate at which feed converts into milk or meat available for human consumption. All other inputs necessary to the production system (eg fossil fuel energy) are left out of this calculation, on an assumption that there are no significant differences between systems. When a meat system in the US is compared with a meat system in Europe, this holds true, but when the comparison is extended to livestock production in most drylands mixed-systems, the assumption that there are no significant differences in non-feed inputs is completely untrue.

Estimates for the US pork-production system, indicate that behind every calorie of feed input there are ten calories of non-feed inputs. Similar estimates in pastoral systems show a reversed ratio, with 0.1 calorie of support energy needed for every calorie of feed input, or a one hundred fold higher efficiency.[111] The difference is due to most support energy coming from human labour.

Assuming uniformity in consumption habits.

There is a similar incongruence in what is considered to be energy available for human consumption within different systems of production. Most pastoral systems operate in market and cultural contexts where the proportion of the animal used for human consumption is generally much higher than in the industrial livestock sector. On many African food markets, (certain) bovine skins, offal and bones (including the whole head and the hooves) qualify for human consumption. The ecological efficiency of any livestock system in Europe or the US would drop dramatically purely on a methodological basis if measured by such eating standards. Substantial output from drylands livestock systems currently remains uncounted for because it is outside the standard definition of output.

Moreover, the assessment of ecological efficiency also usually stops at the farm gate. From a food-chain perspective – especially when framed in a global concern for food-security as these assessments often are – it is an odd decision. The core function of a food production system is to feed people. Hence, one would expect an analysis of a food system's ecological efficiency to embrace the entire chain, including post-production and consumption, especially as differences in ecological efficiency are not likely to be consistent along the chain. High production systems are usually associated with huge losses at consumption stage. Food waste in industrialized countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton) – the largest proportion of these losses (over 40 per cent) occurs at the retail and consumer levels.[112]

A structural difference not a structural limitation

Traditional explanations of small-scale dryland agriculture and pastoralism placed great emphasis on terms like scarcity, fragility and risk. New understanding of drylands variability is reversing this perspective, but this understanding has not yet filtered out far into policy change – and still has some way to go before it reaches economic analysis and mechanisms for appraisal. It is therefore crucial to keep in mind that, more often than not, on-going statements about drylands tend to 'pull to the side' – a bit like a car with a wheel-alignment problem.

When looking at dryland producers it is important to see the multiple reasons behind their choices, be it selecting a particular breed or a particular crop production strategy, and to refrain from comparing production systems across structural differences. Understanding drylands variability as a structural difference rather than a structural limitation means accepting that cause and effect are often impossible to disentangle; that the highest returns come from managing risk risks not avoiding it; and that multiple strategies of specialised integrated production exist in discontinuous, open-ended systems across vast scales throughout the drylands.

Locally based agriculture is still largely capable of feeding local populations in the drylands, and is indeed supporting rapid demographic growth in some areas. Failures are more likely to occur when existing systems of production are replaced by the 'temptation to be in control' – grand schemes that appear to offer environmental stability and economic gain, but which by failing to take the whole picture into account, with its dynamic correlations, can increase exposure to disaster.

"The magical contribution of groups like the Raika of Rajasthan, to food production, out of degraded and depleting Commons, continues; yet is unsung and unheralded. With adaptation methods honed over centuries, their practice is likely to best withstand future periods and adverse effects of climatic stress."

GB Mukherji
Retired Civil Servant and social observer, India.

Left: Herders look at a dusty plain in Awash Fentale district, Ethiopia – an area of grassland before it was cleared for commercial agriculture.

Recommendations on drylands variability

Engage realistically with drylands variability

The variability found in drylands environments is structural – it is not going away anytime soon. If we are to pursue the goal of resilient production and livelihood systems in dryland areas, a fundamental re-qualification of dryland 'problems' and 'solutions' is required – a reality check. As this book has demonstrated, in dryland areas there are no permanent 'best' solutions: by definition the variability means that there can't be a standard response. The 'solution' for drylands is to increase levels of optionality. From the perspective of small-scale producers, this means keeping options open and maximising the capacity to undertake real-time choices from among a variety of potential strategies. Policy can support the creation of these risk management strategies. At the same time, institutional early warning and risk-management systems are needed to deal with scales of risk that are outside the reach of farmers and pastoralists. Above all, realistic management support should refrain from the temptation to exert control and instead focus on strengthening capacity for real-time adaptation.

Support the logic behind dryland food production

In the new understanding of the drylands, it is the selection of the production strategy that determines whether climatic variability is experienced as a problem or an asset. Beyond local differences, all adaptive food production in the drylands shares the logic of interfacing the variability in the environment by embedding variability in the production system. Policy needs to support this logic at all scales and in any way possible. Market integration alone is not flexible and fast enough to effectively interface dryland variability as the sole way of mediating access to resources.

Understand integration as a multitude of paths

Engaging at all scales with the logic of dryland food production includes revisiting the understanding of crop-livestock integration, and more generally the integration of dryland food production with other livelihood strategies, beyond the tunnel vision on the farm scale. In the drylands, the conceptual separation of livestock and crop farming – or their definition at the household level and in isolation from other livelihood strategies – is arbitrary, and leads to undesirable separation and isolation in practice.

Acknowledge the legacy of past interventions

As well as recognising the logic behind food production, it is also important to see that for most of its history drylands development was oriented in the wrong direction. The U-turn in the understanding of drylands is relatively recent, which makes the legacy of past interventions (intended and unintended), a constitutive part of current problems in dryland regions: a legacy that is yet to be fully recognised and addressed. For example, todays' statistical data on the drylands are relatively scanty and unreliable, and many of the analytical tools and mechanisms of appraisal they use were developed under the previous equilibrium model. There is a pressing need to develop and adapt the toolbox for generating representative data in contexts dominated by variability.

Engage with dynamic correlations

Reducing local contexts to sets of discrete problems is not the way forward: instead the approach needs to be able to capture how problems correlate. Capacity needs to be built to detect the problematic legacy of single-path approaches in development, and to look for prospected 'solutions' that are already in place in unexpected forms. Analytical tools need to be capable of recognising correlations (rather than concealing them by focussing on separation). Grand schemes that appear to offer environmental stability and economic gain, but which fail to take into account dynamic correlations, will increase exposure to disaster.

Build social capital and complementarity rather than isolation and competition

Social capital (relationships) becomes more important as environmental risk and uncertainty increase. A general requirement for operating a successful dryland economy is the existence of strong social capital within and across all groups of producers, and at least a functional level of confidence between small producers and government. Social capital is hard to create and easy to lose. Rebuilding this trust needs time, patience and resources on all sides. The creation of suitable services capable of interfacing variability (by the drylands' adaptive logic of embedding variability) is also needed, especially health and education.

Give small-scale producers a second chance

The lack of a second chance discourages risk-taking by entrepreneurs, at a cost to the economy and nations as a whole. In the drylands, the productivity of small-scale operations depends on risk-taking strategies under conditions of risk management – situations where risk aversion and risk management may go in opposite directions. There need to be institutions and safety nets that can guarantee a minimum income and give a second chance to risk-taking small-scale producers hit by a bad year. This might include delivering micro-finance products, risk insurance and appropriate banking services. As social capital is key in risk management, small-scale producers should be engaged with as cooperating networks rather than as competing units.

Engage with new communication opportunities

The extension to the drylands of mobile communication and the Internet has fundamentally transformed the meaning of remoteness, scattered populations and mobility. Combined with the U-turn in the scientific understanding of the drylands, this IT revolution is opening a whole new landscape of opportunities for development and research.

So, how many times in the last week did you operate with underlying assumptions of uniformity and stability? More and more, variability is becoming the baseline of production. Money and goods criss-cross the world in ever more complex and intertwined trajectories, as so do people and crises, making our old trust in a finally prevailing state of stability a potentially lethal trap. This reality can no longer be dismissed as a disturbance or a limitation: it must be engaged with as a structural difference with its own opportunities. Supporting the small-scale producers in drylands who already know how to work with variability rather than against it, is an important step in this direction.

Endnotes

1 http://www.iucn.org/about/union/secretariat/offices/asia/asia_news/?3837/A-few-facts-about-drylands
2 http://www.fao.org/fileadmin/user_upload/drought/docs/Biodiversity-in-the-Drylands-Challenge-Paper.pdf
3 Bai, Z.G., Dent, D.L., Olsson, L. and Schaepman, M.E., 2008. Proxy global assessment of land degradation. Soil Use and Management, 24, 223–234.
4 Bonkoungou, E.G. 2010. Biodiversity in Drylands. Challenges and Opportunities for Conservation and Sustainable Use. http://www.fao.org/fileadmin/user_upload/drought/docs/Biodiversity-in-the-Drylands-Challenge-Paper.pdf .
5 Mortimore, M. ed., 2009 Dryland Opportunities: A new paradigm for people, ecosystems and development, pp. 27-41. IUCN, Gland, Switzerland, IIED, London, UK and UNDP, New York, USA.
6 Saundry, Peter. 2011. Ecosystems and Human Well-Being: Volume 1: Current State and Trends: Dryland Systems. http://www.eoearth.org/view/article/169757/
7 Developing nations have 'more to lose' from loss of drylands http://www.scidev.net/global/biotechnology/news/developing-nations-have-more-to-lose-from-loss-of-drylands-.html#sthash.3ZsaousZ.dpuf
8 Singh, Arvind. 2015. Dryland Agriculture in India. Need to Enhance Agricultural Production for Combating Hunger and Malnutrition and Improving the Plight of Farmers. http://www.sciencelog.net/2015/02/dryland-agriculture-in-india.html
9 "Drylands are not Wastelands". Interview with Julia Marton-LeFevre, Director General of the International Union for the Conservation of Nature (IUCN) http://gahlm.unccd.int/#LeFevre
10 Agrobiodiversity in drylands, http://www2.gtz.de/dokumente/bib-2011/giz2011-0025en-agrobiodiversity-drylands.pdf
11 http://www.unccd.int/Lists/SiteDocumentLibrary/WDCD/DLDD%20Facts.pdf, http://www.fao.org/fileadmin/user_upload/newsroom/docs/i0372e01.pdf
12 Valente, Marcela. 2012. Argentina: Three-Quarters of "Breadbasket" Is Drylands. http://www.ipsnews.net/2012/02/argentina-three-quarters-of-breadbasket-is-drylands/
13 Hoekstra, A. Y. 2010. 'The water footprint of animal products'. In J. D'Silva and J. Webster (eds.) The Meat Crisis: Developing More Sustainable Production and Consumption, Earthscan, London, pp. 22–33.
14 Koohafkan, Parviz. 2012. Water and Cereals in Drylands. London: Routledge.
15 Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R., Winslow, M., Ziedler, J., Prince, S., Archner, E., King, C., 2005. Dryland systems. In: Hassan, R Scholes, R.J., Ash, N. (Eds.), Ecosystems Human Well-Being. Findings of the Conditions Trends Working Group of the Millennium Ecosystem Assessment, vol. 1. Island Press, Washington D.C., U.S.A, pp. 623–662.
16 http://www.roaddriver.co.uk/safety-tips/how-to-control-your-car-during-a-puncture-or-tyre-blowout
17 Koohafkan P. and Stewart B.A. 2008. Water and Cereals in Drylands, FAO and Earthscan, London and Sterling VA, p. 11.
18 Dyson-Hudson N. 1958. The Present Position of the Karimojong. A preliminary general survey, with recommendations, produced for the Government of Uganda, Oxford University, Institute of Social Anthropology, p. 6.
19 Under the UNCCD classification, drylands are defined by a ratio of precipitation over potential evapotranspiration (P/PET) between 0.05 and 0.65 (Koohafkan and Stewart, op. cit.: 5).
20 FAO defines as 'drylands' the ensemble of the areas where the length of growing period is between 1 and 179 days (with LGP=1 day defining hyper-arid areas or true deserts; less than 75 days defining arid lands; 75-120 days defining semiarid lands; and 120-179 days defining dry-subhumid areas).
21 The 'length of growing period' was rooted into the UNCCD definition of drylands, and defined as: 'the continuous period of the year when precipitation exceeds half of Penman evapotranspiration, plus a period required to evapotranspire an assumed moisture reserve when mean temperature exceeds 6.5 degrees Celsius' (cf. FAO 1996. Agro-Ecological Zoning. Guidelines. FAO Soils Bulletin 73, FAO Land and Water Development Division, Food and Agriculture Organization of the United Nations, Rome).
22 Mortimore, M. and Adams, W.M. 1999. Working the Sahel, Routledge, London.
23 In experiments with cut hay, ruminants preferred to feed on the afternoon cut. Dairy cows feed forage harvested in the late afternoon have been observed to eat more and produce more milk (Kim, D. 1995. Effect of plant maturity, cutting, growth stage, and harvesting time on forage quality. Ph.D. Dissertation. USU, Logan, UT; Mayland H.F. 2000. Diurnal Variation in Forage Quality Affects Preference and Production, http://www.uwex.edu/ces/forage/wfc/proceedings2000/mayland.htm; Orr R.J., Penning P.D., Harvey A. and Champion R.A. 1997. Diurnal patterns of intake rate by sheep grazing monocultures of ryegrass or white clover. Appl. Animal Behav. Sci. 52: 65-77). Grass harvested in the afternoon has been observed to contain significantly higher crude protein, mono- and disaccharides, total nonstructural carbohydrate, and in-vitro dry matter digestibility (Mayland H.F., Shewmaker G.E., Burns J.C. and Fisher D.S. 1998. Morning and Evening Harvest Effects on Animal Performance, http://alfalfa.ucdavis.edu/Symposium/1998/AM_PM%20Harvest%20Effects.htm).
24 Schareika N., Graef F., Moser M. and Becker K. 2000. Pastoral Migration as a Method of Goal-oriented and Site-specific Animal Nutrition among the Wodaabe of South-eastern Niger. Die Erde 131: 312-329.
25 Cf. Breman and De Wit, (op. cit.: 1343): 'In the Sahel countries, water limits growth at the border of the Sahara […] With water availability rising from 50 to 1000 mm annually the total mean production increases from nearly 0 to 4 metric tons per hectare. The protein content in the fully grown plants declines from 12 to 3 percent. Thus low water availability produces a small amount of biomass of good quality, and higher water availability results in more biomass of increasingly inferior quality'.
26 On the Sahel: Breman and De Wit, op. cit. On Mongolia: Vetter S. (ed.) 2004. Rangelands at equilibrium and non-equilibrium: Recent developments in the debate around rangeland ecology and management, Programme for Land and Agrarian Studies, University of the Western Cape., Cape Town, Republic of South Africa.
27 Cf. on pastoral ecosystems in Kazakstan: 'in the case of Agropyron there is a drop from 5.3 per cent protein and 10.5 per cent cellulose at heading phase to 1.7 per cent protein and 15.9 per cent cellulose when seeded out' (Alimaev I.I. 2003. Transhuman ecosystems: fluctuations in seasonal pasture productivity. In: Kerven, C. ed. Prospects for Pastoralism in Kazakstan and Turkmenistan: From State Farms to Private Flocks, Routledge-Curzon, London).
28 IIED and SOS Sahel 2009. Modern and Mobile. The future of livestock production in Africa's drylands. Edited by Helen de Jode, International Institute for Environment and Development, and SOS Sahel International UK, London.
29 Breman H. and De Wit C.T. 1983. Rangeland Productivity and Exploitation in the Sahel. Science, New Series, 221(4618): 1341-1347.
30 Mortimore and Adams, op. cit.
31 World Bank, Natural Resource Institute and FAO 2011. Missing Food. The Case of Postharvest Grain Losses in Sub-Saharan Africa. Report No. 60371-AFR, The International Bank for Reconstruction and Development / The World Bank, Washington, DC.
32 National Research Council (US) 1978. Postharvest Food Losses in Developing Countries, National Academy of Science, Washington DC.
33 Kanwar P and Sharma N. 2003. An insight of indigenous srop storage practices for food security in Himachal Pradesh, in Kanwar, S.S., Sardana, P. K., and Styavir (Ed.) Food and Nutritional Security: Agrotechnology and socio-economic aspects, SAARM, India? 175-179.

34 Boxall et al 2004. Sorghum, in Hodges, R. and Farrell, G. (Eds.) Crop Post-Harvest: Science and Technology, Vol 2- Durables. NRI and Blackwell Publishing: Oxford.

35 Roe E. 2013. Making the Most of Mess. Reliability and Policy in Today's Management Challenges, Duke University Press, Durham and London. Roe E. and Schulman P.R. 2008. High Reliability Management. Operating on the edge, Standford Business Books, Standford University Press, Standford, CA. Roe E., Huntsinger L. and Labnow K. 1998. High Reliability Pastoralism. Journal of Arid Environments 39 (1): 39-55.

36 Roe E. op cit:6

37 Walker B.H., Ludwig D., Holling C.S. and Peterman R.M. 1981. Stability of semi-arid savanna grazing systems. Journal of Ecology 69(2): 473-498, p.473.

38 The seminal works leading to the paradigm shift are well known, amongst others: Sandford S. 1983. Management of Pastoral Development in the Third World, John Wiley & Sons, Chichester, England; Ellis J.E. and Swift D.M. 1988. Stability of African ecosystems: alternate paradigms and implications for development. Journal of Range Management 41 (6): 450-459; Westoby, M., B. Walker, and I. Noy-Meir 1989. Opportunistic management of rangelands not at equilibrium. Journal of Range Management 42: 266–274; Behnke R.H., Scoones, I. and Kerven C. (eds) 1993. Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas, Overseas Development Institute, London; Scoones I. (ed.) 1994. Living with Uncertainty: New Directions in Pastoral Development in Africa, Intermediate Technology Publications Ltd, London. Although the paradigm shift was formalised in the anglophone literature, a parallel reflection on the economic importance of pastoral mobility was also taking form in the francophone context, for example in the works of: Benoit M. 1982. Nature Peul du Yatenga. Remarque sur le Pastoralisme en Pays Mossi, OSTROM, Paris; Bernus E. 1990. En guise de conclusion: les pasteurs nomades africains, du mythe éternel aux réalités présente. Cah. Sci. Hum. 26(7-2): 267-280; Digard J.P., Landais E., Lhoste Ph. 1992. La crise des sociétés pastorales. Un regard pluridisciplinaire. Rev. Elev. Méd. Vét. Pays Trop. 46(4): 683-692.

39 Behnke R.H. and Scoones I. 1993. Rethinking range ecology: implications for rangeland management in Africa. In: Behnke et al. op. cit.

40 FAO 2002. Pastoralism in the New Millennium, FAO Animal Production and Health Papers no. 150. Food and Agriculture Organization of the United Nations, Rome. Rass N. 2006. Policies and Strategies to Address the Vulnerability of Pastoralists in Sub-Saharan Africa, PPLPI Working Paper No. 37, Pro-Poor Livestock Policy Initiative, FAO, Rome. UNDP-GDI 2003. Pastoralism and Mobility in the Drylands. GDI Challenge Paper Series, The Global Drylands Imperative (GDI), United Nations Development Programme, Drylands Development Centre, Nairobi, Kenya. IUCN 2011. Supporting Sustainable Pastoral Livelihoods: A Global Perspective on Minimum Standards and Good Practice. Second Edition March 2012 (published for review and consultation through global learning fora), IUCN ESARO office, Nairobi. AGIR 2013. AGIR- Sahel and West Africa. Regional Roadmap. Adopted on 9 April 2013, Global Alliance for Resilience, Paris. AFD 2013. Élevage pastoral. Une contribution durable au développement et à la sécurité des espaces saharo-sahéliens N'Djamena (Tchad), 27-29 mai 2013, Agence Française du Developpement- Tchad, N'Djaména. De Haan C., Dubern E., Garancher B., and Quintero C. 2014. Pastoralism Development in the Sahel: A Road to Stability? , Global Center on Conflict, Security and Development, The World Bank, Washington DC.

41 Breman and De Wit op. cit.; Behnke and Scoones, op. cit. Oba G., Stenseth, N.C. and Lusigi, W.J. 2000. New perspectives on sustainable grazing management in arid zones of sub-Saharan Africa. BioScience 50: 35-51. Krätli S. and Schareika N. 2010. Living off Uncertainty. The Intelligent Animal Production of Dryland Pastoralists. European Journal of Development Research 22(5): 605-622.

42 Mortimore and Adams, op. cit.

43 Atsbaha Gebre-Selassie (pers comm) See also: https://www.researchgate.net/publication/229612492_Removal_of_rock_fragments_and_its_effect_on_soil_loss_and_crop_yield_Tigray_Ethiopia

44 WRI 2008. Roots of resilience: Growing the wealth of the poor, World Resources Institute, Washington, D.C.

45 Larwanou, Abdoulaye, and Reij 2006, cited in Reij C. and Smale M. 2009. Re-Greening the Sahel: Farmer-led innovation in Burkina Faso and Niger. In: Spielman D.J. and Pandya-Lorch R.(eds) Millions fed: proven successes in agricultural development,, International Food Policy Research Institute, Washington.

46 Cf. De Haas H. 2001. Migration and Agricultural Transformations in the oases of Morocco and Tunisia, KNAG, Utrecht.

47 Text based on a series of short case studies by Seth Cook.

48 Zhu X., Anquan L. and Yisheng J. 1990. "Soil erosion and soil conservation in the Loess Plateau of northwestern China." In Hong Qingwen and Chen Peilin, eds., Soils of China. Beijing: Science Press.

49 Gao Q., Xiaoyan L. and Faming L. 2001. Perspectives of development and utilization of rainwater harvesting in the arid region of China, in the Proceedings of the China National Symposium and International Workshop on Rainwater Utilization, July 22-26, Lanzhou, China.

50 For a more extensive discussion of rainwater harvesting agriculture, see : Cook, Seth, Li Fengrui and Wei Huilan. 2000. Rainwater harvesting in Gansu Province, People's Republic of China, Journal of Soil and Water Conservation 55(2): 112-114; and Li, Fengrui, Seth Cook, Gordon T. Geballe and William R. Burch. 2000a. Rainwater harvesting agriculture: an integrated system for water management on rainfed land in China's semi-arid areas, Ambio 29(8): 477-483.

51 van den Brink R., Bromley D.W. and Cochrane J.A. 2008. Property rights and productivity in Africa: Is there a connection? Development Southern Africa 11(2): 177-182, p. 18.

52 Mortimore, M. & Adams, op. cit., p20.

53 van den Brink, R., Bromley, D. W., and Chavas, J. 1991. The economics of Cain and Abel: agro-pastoral property rights in the Sahel, Working paper 11, Cornell Food and Nutrition Policy Program, Washington, p. 7, http://pdf.usaid.gov/pdf_docs/PNACB225.pdf

54 Text based on Critchley W., Gaiballa A., Eissa A.O., Deen A.M., and Mollee E. 2012. 'Ancient traditions receiving a new impetus' Ch 9 in: Critchley W. and Gowing J. (eds) Water Harvesting in South Saharan Africa, Earthscan, London.

55 Based on the case study 'Agronomies of Risk and Resilience: Adaptation and Innovation in Rainfed Farming in India' by Rajeswari S. Raina (with Ravindra, A., Ramachandrudu, M. V., Kiran, S. and Sneha, A.)

56 Voelcker, J. A. 1893. Report on the Improvement of Indian Agriculture, Eyre and Spottiswoode for Her Majesty's Government, London (Reprinted in 1986 by Agricole Reprints Corporation, New Delhi); Royal Commission on Agriculture .1928. The Report of the Royal Commission on Agriculture in India. H M Stationery Off. London (Abridged Version, 755 pgs); and Umrani 1999, quoting the Bombay Dry Farming Method of the 1930s).

57 Famine Inquiry Commission, 1885. Report of the Indian Famine Commission, 1880-1885. Reprinted by Agricole Reprints Corporation, New Delhi in 1989.

58 Planning Commission. 2013. Twelfth Five Year Plan (2012-17) – Economic Sectors, Volume II, Planning Commission, Government of India. SAGE, New Delhi. (p. 46-47)

59 Raina, R. S. 2014. Beyond Supply Driven Science Seminar, 654. 69-74.

60 Ruttan, V. W., 2005. Scientific and technical constraints on agricultural production: Prospects for the future, Proceedings of the American Philosophical Society, 149 (4):453-468

61 Provenza F.D. and Launchbaugh K.L. 1999. Foraging on the Edge of Chaos. In: Launchbaugh K.L., Mosley J.C. and Sanders K.D. (eds). Grazing Behavior in Livestock and Wildlife. Pacific Northwest Range Short Course, Station Bulletin No. 70, University of Idaho, Moscow, ID.

62 Marty A., Eberschweiller A. and Dangbet Z. 2009. Au Coeur de la Transhumance. Un Campement chamelier au Tchad central. September 2006-Avril 2007, Antea, IRAM, Karthala, Paris et Orléans.

63 Cf. Schareika et al (op. cit.: 322), on the Wodaabe of Niger: 'The herders's preference of Heliotropium ovalifolium (yaharehi) against other herb species demonstrates this rationality. They say that Heliotropium ovalifolium stays fresh even when the dry season comes [...] and the cattle's droppings are like the droppings of the fresh matter period [...] Some other herbs and creepers highly valued for this reason are Indigofera Hochstetteri (jaa'oomaahi), Ipomoea verticillata (amaseekel); Corchorus tridens and Corchorus olitorius (laala) and Cucumis melo (yamBuruuwol)'.

64 Kaufmann B.A. 2007. Cybernetic Analysis of Socio-biological Systems: The Case of Livestock Management in Resource-Poor Environments, Margraf Publishers GmbH, Weikersheim. Krätli S. 2008. Cattle breeding, Complexity and Mobility in a Structurally Unpredictable Environment: the WoDaaBe herders of Niger. Nomadic Peoples 12(1): 11-41.

65 Meuret M. and Provenza F. (eds) 2014. The Art and Science of Shepherding. Tapping the Wisdom of French Herders, ACRES, Austin, TX.

66 Andrei Marin, researcher, Norwegian University of Life Sciences, Aas, Norway and Mikkel Nils Sara reindeer herder and researcher Sámi Allaskuvla/Sámi University College, Kautokeino, Norway

67 Schiere H. (JB), Baumhardt R.L., Van Keulen H., Whitbread H.M., Bruinsma A.S., Goodchild T (AV), Gregorini P., Slingerland M(MA) and Wiedemann-Hartwell B. 2006. Mixed Crop-Livestock Systems in Semi-Arid Regions. In: G.A. Peterson (ed.), Dryland Agriculture, 2nd ed. Agron. Monogr. 23, American Society of Agronomy Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc., Madison, WI. Scoones I. and Wolmer W. 2002. Crop-livestock integration in Africa. In: Scoones I. and Wolmer W. (eds.), Pathways of Change in Africa. Crops, Livestock & Livelihoods in Mali, Ethiopia and Zimbabwe, James Currey Ltd., London.

68 Kintz, D. 1982. Pastoralisme, Agro-Pastoralisme et Organisation Foncière: Le Cas des Peulhs. In: Le Bris, E., Le Roy E. and Leimdorfer F. (eds). Enjeux fonciers en Afrique noire, Karthala, Paris. Baxter P.T.W. and Hogg R. (eds) 1990. Property, Poverty and People: Changing Rights in Property and Problems of Pastoral Development, University of Manchester, Manchester.

69 Khazanov A.M. and Schlee G. (eds) 2012. Who Owns the Stock? Collective and Multiple Property Right in Animals, Berghahn Books, New York and Oxford.

70 van Raay H.G.T. 1974. Fulani Pastoralists and Cattle, Occasional Paper No. 44, Institute of Social Studies, The Haag.

71 Brink et al 1991, op. cit..

72 Based on the case study ' Coping with Climate Uncertainty: The Maldharis in Maharashtra' by Nitya Sambamurti Ghotge and Dileep Halse (researcher)

73 Schiere et al. op. cit.

74 Text provided by Dr Camilla Toulmin, Director IIED

75 Mahmoud H. 2011. Livestock Marketing Chains in Northern Kenya: Re-Aligning Exchange Systems in Risky Environments. In: Gertel J. and Le Heron R. (eds) Economic Spaces of Pastoral Production and Commodity Systems, Ashgate Publishing Ltd, Farnham, UK.

76 Zaal F. 2011. Pastoral Integration in East African livestock Markets: Linkages to the Livestock Value Chain for Maasai Pastoral Subsistence and Accumulation. In: Gertel J. and Le Heron R. (eds) Economic Spaces of Pastoral Production and Commodity Systems, Ashgate Publishing Ltd, Farnham, UK.

77 Based on the case study 'Rangeland Governance Innovations: Cases from China' by Yanbo Li, Gongbuzeren and Wenjun Li

78 Ministry of Agriculture 2011. Report on Monitoring of China's rangeland conditions in 2010, Government of China, Beijing. http://www.grassland.gov.cn/Grassland-new/Item/2819.aspx

79 Piao S., Ciais P., Huang Y., Shen Z., Peng S., Li J., Zhou L., Liu H., Ma Y., Ding Y., Friedlingstein P., Liu C., Tan K., Yu Y., Zhang T. and Fang J. 2010. The Impacts of Climate Change on Water Resources and Agriculture in China, Nature 467(7311): 43-51.

80 Li, W.J. and Huntsinger L. 2011. China's Rangeland Contract Policy and its Impacts on Herder Ability to Benefit in Inner Mongolia: Tragic Feedbacks, Ecology and Society 16 (2): 1.

81 Li, Y.B., Gongbuzeren, Li. W.J. 2014. A Review of China's Rangeland Management Policies. IIED Country Report. IIED, London, http://pubs.iied.org/10079IIED

82 http://en.wikipedia.org/wiki/Oscar_Pistorius http://www.scientificamerican.com/article/scientists-debate-oscar-pistorius-prosthetic-legs-disqualify-him-olympics/

83 Taken from the case study 'Provision of education amidst discontinuity in nomadic communities' by Laban Peter Ayiro.

84 Berkes F. and Folke C. (eds) 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, Cambridge Univ. Press , Cambridge, UK.; Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecological Systems 4:1–23.

85 Based on the case study 'Ethiopia's Omo-Gibe River and the Turkana Basin: A case study of objections to major hydropower and irrigation development in Ethiopia' by Sean Avery

86 Based on the case study 'What's new about the new wave of irrigation development in the drylands of Kenya? A case of Turkwel, Turkana County' by Gregory Akall.

87 http://en.wikipedia.org/wiki/Who_Dares_Wins

88 Discussed in Roe et al 1998, op. cit.

89 Based on the case study 'Documentation and quantification of a long distance migratory sheep husbandry system in Southern Rajasthan' by Ilse Koehler-Rollefson, Hanwant Singh Rathore, Dailibai Raika, and Jagdish Paliwal

90 The nomadic shepherding system was described by Kavoori P.S. 1999. Pastoralism in Expansion: The Transhuming Herders of Western Rajasthan. Oxford University Press, New Delhi.

91 A detailed description of the organization and decision making structures of Raika shepherds, is in Agrawal A. 1999. Greener pastures: politics, markets, and community among a migrant pastoral people, Duke University Press, Durham, North Carolina, USA and London.

92 This is a conservative estimate. The Rajasthan Development report from 2006 estimated that there were 200 000 shepherds in the state and 3 million sheep slaughtered per year, resulting in 33 million Kg of mutton.

93 Pica-Ciamarra U. et al. 2014. Investing in the Livestock Sector. Why Good Numbers Matter. A Sourcebook for Decision Makers on How to Improve Livestock Data, World Bank Report Number 85732-GLB, The World Bank and FAO, Washington.

94 Penning de Vries, F.W.T. 1983. The Productivity of Sahelian Rangelands: A Summary Report. Pastoral Network Paper No. 15b, Overseas Development Institute (ODI), London.

95 According to Harvard psychologist Howard Gardner, cf. Gardner H. 1999. Intelligence Reframed. Multiple Intelligences for the 21st Century, Basic Books, New York.

96 Cf. Shaw and Colville (1950): 'The basic problem concerning any livestock improvement in Nigeria is not one in the first instance for the geneticist, but for the animal feeder' (Shaw T. and Colvile G. 1950. Report of Nigerian Livestock Mission. Colonial No. 266: 1-175, HMSO, London, p.17). Also Pagot (1952): 'Having observed the huge influence of climatic variations on milk production, one is naturally driven to think that any improvement of livestock production through genetic means will have insignificant impact in the long term if compared to the returns that could be obtained by optimising feeding' (Pagot J. 1952. Production laitière en zone tropicale. Faits d'expérience en A.O.F.. Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux N.S. 5: 173-190, p. 190). 97 Scoones I. and Wolmer W. 2002. Crop-livestock integration in Africa. In: Scoones I. and Wolmer W. (eds.), Pathways of Change in Africa. Crops, Livestock & Livelihoods in Mali, Ethiopia and Zimbabwe, James Currey Ltd., London.

98 Schiere et al. op. cit.: 38.

99 Scherf B. (ed.) 2000. World Watch List for Domestic Animal Diversity. 3rd edition, FAO, Rome.
100 Oba G., Stenseth N.C. and Lusigi W. 2000. New perspectives on sustainable grazing management in arid zones of sub-Saharan Africa. Bioscience 50: 35-51.
101 This is particularly frequent for example in UN literature: UNCCD; UNEP; FAO; IFAD.
102 UNDP 2003. The Global Drylands Imperative. Land Tenure Reform and the Drylands, African Centre for Technology Studies, Centre for International Sustainable Development Law, United Nations Development Programme, Nairobi.
103 Neely C., Bunning S. and Wilkes A. 2009. Review of evidence on drylands pastoral systems and climate change. Implications and opportunities for mitigation and adaptation, FAO Land Tenure and Management Unit (NRLA), Rome.
104 IDDC 2012, http://www.apaari.org/wp-content/uploads/downloads/2012/05/11thICDD-First-Circular-2.doc
105 Turner B.L. and Benjamin P. 1994. Fragile lands: identification and use for agriculture. In: Ruttan V. (ed.) Agriculture, Environment and Health: sustainable development in the 21st century, University of Minnesota Press, Minneapolis.
106 Wood S., Sebastian K., Nachtergaele F., Nielsen D. and Dai A. 1999. Spatial Aspects of the Design and Targeting of Agricultural Development Strategies, Environment and Production Technology Division, International Food Policy Research Institute (IFPRI), Washington D.C.
107 Holling C.S. 2001. Understanding the Complexity of Economic, Ecological, and Social Systems. Ecosystems 4: 390–405. Walker B. 2006. Riding the rangelands piggyback: a resilience approach to conservation management. In: du Toit J., Kock R. & Deutsch J. (eds) Wild Rangelands: Conservation in the World's Grazing Ecosystems, Blackwells, Oxford. Folke C., Carpenter S., Walker B., Scheffer M. Elmqvist T., Gunderson L. and Holling C.S. 2004. Regime shifts, resilience and biodiversity in ecosystem management. Annu. Rev. Ecol. Evol. Syst. 35: 557–81.
108 Mortimore and Adams, op. cit. Reij and Smale op. cit. Faye, A., Fall, A., Tiffen, M. and Nelson, J., 2001. Région de Diourbel: synthesis. Drylands Research Working Paper 23e. Drylands Research, Crewkerne, UK. Mazzucato, V. and Niemeijer, D., 2000. Rethinking soil and water conservation in a changing society. Tropical Resource Management Paper 32. Wageningen University and Research Centre, Wageningen. Mortimore, M., Tiffen, M., Boubacar, Y. and Nelson, J., 2001. Synthesis of long-term change in Maradi Department, Niger, 1960-2000. Drylands Research Working Paper 39e, Drylands Research, Crewkerne, UK.
109 Based on the case study by Athar Parvaiz
110 Based on the case study by Athar Parvaiz 'Banni Pastoralists: Courting Success in Search of Survival'
111 Gliessman, S.R. 2007. Agroecology: The ecology of sustainable food system. Zweite Auflage. CRC Press, Boca Raton.
112 Gustavsson J., Cederberg C., Sonesson U. and van Otterdijk R, Meybeck A. 2011. Global Food Losses and Food Waste. Extent, Causes and Prevention, Food and Agriculture Organization of the United Nations, Rome. For a recent document on food wastage, see FAO-FWF 2014. Food Wastage Footprint. Full-cost accounting. Final Report, FAO, Rome.

Photo credits

Cover Kalyan Varma
p2 Kelley Lynch
Han Jianping
Partha Pal (Getty images)
p6 Kelley Lynch
Wenjun LI
Han Jianping
Ilse Koehler-Rollefson/
LPPS archives
P8 Ashok Captain
p10 Han Jianping
p12 Michael Benanav
p 14 Marie Monimart
Greg Akall
Ilse Koehler-Rollefson/
LPPS archives.
p16 Robin Wyatt/IIED
Decann Development
Society.
p 18 Marie Monimart/IIED
Ced Hesse
p 20 Michael Benanav
p 22 Han Jianping
p 26 Kelley Lynch
p 28 Tao Wang
p 30 Michael Benanav
p 32 Han Jianping
Jan Nyssen
p 34 Han Jianping
p 36 Will Critchley
p 38 Rajeswari Raina
p 40 Kenya Markets Trust,
reprinted with kind
permission.
Ashok Captain
p 42 Yupei LAI
N. Schareika
p 44 Eva Martensson
(Getty Images)
Andrei Marin
p 46 Ilse Koehler-Rollefson/
LPPS archives
Ashok Captain
p 48 Ashok Captain
p 50 Michael Benanav
Hari Mitharam Bharwad
p 52 Camilla Toulmin
p 54 Kelley Lynch
p 56 Yupei LAI
p 58 Michael Benanav
p 60 Ilse Koehler-Rollefson/
LPPS archives.
p 62 Michael Benanav
p 64 Molu Kullu
p 66 Kelley Lynch
p 70 Ilse Koehler-Rollefson/
LPPS archives.
p74 Alan Hesse (catoonist)
p 76 Wenjun LI
p 78 Sahjeevan
p 80 Kelley Lynch
p83 Ashok Captain
p88 Decann Development
Society

About the partners

DLCI

The Drylands Learning and Capacity Building Initiative for improved policy and practice in the Horn of Africa (DLCI) is a knowledge management and advocacy resource organization registered in Kenya. It supports collaborative learning and documentation on drylands development, and advocacy for improved policy and practice in the region.

RLN

The Rainfed Livestock Network is a consortium of organisations in India that work in the sectors of livestock and natural resource management (NRM) with a focus on the drylands and pastoral communities.

RRA Network

Revitalization of Rainfed Agriculture Network is striving to create enabling and relevant policies and programs for strengthening rain-fed agriculture in India. About 300 members are part of this network including WASSAN, Samaj Pragati Sahyog and several reputed institutions.

Peking University

Peking University is a major Chinese research university located in Beijing and a member of the C9 League. It is the first established modern national university of China, founded as the "Imperial University of Peking" in 1898 as a replacement of the ancient Guozijian. Peking University is a comprehensive national key university, consisting of fifty schools.

IIED is a policy and action research organisation promoting sustainable development and linking local priorities to global challenges.

We are based in London and work on five continents with some of the world's most vulnerable people to strengthen their voice in the decision-making arenas that affect them.


iied