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Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya

Chinwe Ifejika Speranza · Boniface Kiteme · Peter Ambenje · Urs Wiesmann · Samuel Makali

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Abstract This article describes the indigenous knowledge (IK) that agro-pastoralists in larger Makueni District, Kenya hold and how they use it to monitor, mitigate and adapt to drought. It examines ways of integrating IK into formal monitoring, how to enhance its value and acceptability. Data was collected through target interviews, group discussions and questionnaires covering 127 households in eight villages. Daily rainfall data from 1961–2003 were analysed. Results show that agro-pastoralists hold IK on indicators of rainfall variability; they believe in IK efficacy and they rely on them. Because agro-pastoralists consult additional sources, the authors interpret that IK forms a basic knowledge frame within which agro-pastoralists position and interpret meteorological forecasts. Only a few agro-pastoralists adapt their practices in anticipation of IK-based forecasts partly due to the conditioning of the actors to the high rainfall variability characteristic of the area and partly due to lack of resources. Non-drought factors such as poverty, inadequate resources and lack of preparedness expose agro-pastoralists to drought impacts and limit their adaptive capacity. These factors need to be understood and effectively addressed to increase agro-pastoralists' decision options and the influence of IK-based forecasts on their decision-making patterns. The limited intergenerational transfer of IK currently

C. Ifejika Speranza (✉) · U. Wiesmann
Centre for Development and Environment, Institute of Geography, University of Bern, Hallerstrasse 10, 3008 Bern, Switzerland
e-mail: Ifejika.speran@pingnet.ch, ifejika.speranza@die-gdi.de

C. Ifejika Speranza
Department IV: Environmental Policy and Management of Natural Resources, German Development Institute, Bonn, Germany

B. Kiteme · S. Makali
Centre for Training and Integrated Research in Arid and Semi-Arid Lands Development, Nanyuki, Kenya

P. Ambenje
Kenya Meteorological Department, P.O. Box 30259, 00100 Nairobi, Kenya

threatens its existence in the longer term. One way to ensure its continued existence and use is to integrate IK into the education curriculum and to link IK with formal climate change research through the participation of the local people. However, further studies are necessary to address the reliability and validity of the identified IK indicators of climate variability and change.

1 Introduction

Climate change studies show that Africa is highly vulnerable to climate variability and change (Sivakumar et al. 2005; Boko et al. 2007, p. 435ff), due to multiple stresses and low adaptive capacity. Sivakumar et al. (2005) found projected future area-averaged annual mean warming across Africa to range from 0.2°C per decade to more than 0.5°C per decade. Christensen et al. (2007, p. 866ff) report that 'the warming in all parts of Africa is expected to be larger than the global warming with the African drier subtropical regions warming more than its moister tropics'. In relation to rainfall, Sivakumar et al. (2005) show that rainfall in African arid and semi-arid tropics has changed substantially over the last 60 years and that with small changes in climate noticeable changes may occur in the frequency and intensity of extreme events, including floods. However, climate change projections show that there is likely to be an increase in annual mean rainfall in East Africa. This is in contrast to the Mediterranean and northern Sahara regions that are likely to experience a decrease in rainfall or the West Africa region where it is uncertain how rainfall will evolve (Christensen et al. 2007, p. 866ff). In addition to these projections, the recurrent droughts in the arid and semi-arid tropics of Africa cause water stress and pose the greatest risk to agriculture for these areas. Thus the problem of climate variability and change needs to be addressed from various angles and using different methods in order to achieve effective mitigation and adaptation. One such angle is how indigenous knowledge (IK) can contribute to climate change monitoring, mitigation and adaptation.

The terms IK (Nakashima and Roué 2002), traditional ecological knowledge (TEK; Berkes 1999; Huntington 2000), local knowledge (LK) and local ecological knowledge (LEK; Olsson and Folke 2001; Gilchrist et al. 2005) are used to refer to knowledge that are location specific, acquired through long-term observation of (and interaction with) the environment, and transferred through oral traditions from generation to generation. In this paper we use IK to mean a cumulative body of ecological and non-ecological knowledge, know-how, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission (adapted from Berkes 1999). IK is time, place and culture specific.

While studies on the contribution of IK to climate change research are still few, the contributions of IK to understanding and interpreting ecological processes, and for use in environmental and social impact assessments is widely acknowledged (Berkes 1999; Huntington 2000; Nakashima and Roué 2002; Olsson et al. 2004). These contributions can be related to climate change mitigation and adaptation activities as human activities in the ecological sphere like reforestation can reduce green-house gas (GHG) emissions while the adoption of drought tolerant seeds for example may improve adaptation.

Nyong et al. (2007) show that the people of the African Sahel have used IK in natural resources conservation measures serving the multiple purposes of reducing the emission of GHG from anthropogenic sources, carbon sequestration and carbon substitution. The authors found that the practice of zero tilling, mulching, fallowing, agro-forestry and organic farming are existing ways of creating or maintaining carbon sinks. They report that IK has been used in weather forecasting, vulnerability assessment and implementation of adaptation strategies such as preserving biodiversity, use of emergency fodder in drought times, and multi-species composition of herds and mobility. They suggest that incorporating IK can improve the development of sustainable climate change mitigation and adaptation strategies.

Despite the increasing interest in the use of IK, scepticism towards IK exists and is one of the factors limiting the spread of IK into management practice and science (cf. Gilchrist et al. 2005; Pierotti and Wildcat 2000; Huntington 2000; Leigh Thorpe 1994). This is because IK is sometimes evaluated with the same criteria like science such as formulating and testing hypotheses in an objective manner, or the independent tests of results of scientist A through replication of analysis by scientist B in order to validate scientist A's findings. Yet for the scepticism about the unreliability of IK to be addressed, there is need to carry out assessments of IK at dimensions or levels that are comparable with other forms of knowledge. For example Gilchrist et al. (2005) carried out a comparative analysis of the value of LEK and science for wildlife management of marine bird species and found that in some cases derived data from both forms of knowledge tallied where LEK was collected from people who derived their LEK from direct long-term observations and experiences. The cases where information from both sources differed were attributed to the unfamiliarity of the local people with the species. The authors thus concluded that management decisions that are based mainly on IK, without accompanying scientific scrutiny should be treated with caution (Gilchrist et al. 2005).

The few existing studies on the contributions of IK to climate change research show that IK and science can complement each other (Riedlinger and Berkes 2001; Luseno et al. 2003) through the different types of data collected, the different scales of analysis (IK—location-specific and detailed thus micro-level; formal climate change science—regional and global scales thus meso- to macro-level); and the temporal scales at which both forms of knowledge are generated (IK—continuous; modern climate change analysis—monthly, yearly). Studies show that IK can contribute to fill gaps in formal seasonal forecasts, which are largely at broader spatial and temporal scales (Luseno et al. 2003). Luseno et al. (2003) suggest that indigenous climate forecasting methods can offer insights to improving the value of modern seasonal forecasts for pastoralists in East Africa as indigenous forecasting methods are need driven, focus on the locality, on the timing of rains, and indigenous forecasts are 'communicated in local languages and typically by "experts" known and trusted by pastoralists' (Luseno et al. 2003, p. 1484). On the other hand modern forecasts are made at very low spatial resolutions, focus on rainfall amounts rather than on the timing of the rains, which is of greatest importance to the pastoralists because their 'migration patterns depend on when grass and water are available in different sites, and not on the average availability over a period' (Luseno et al. 2003, p. 1484). Berkes and Jolly (2001) show that linking IK to climate change science is a viable way to involve local communities. Further, IK can offer different perspectives to academic questions (Cruikshank 2001), provide opportunities to science for hypothesis testing on the impacts of climate change, enrich known observations, improve existing data, and contribute new insights to understanding weather at a local scale (Leigh Thorpe 1994; Riedlinger 1999). IK is found to be of special importance to adaptation as it is at the local level that people have to adapt to the impacts of climate change and need to have the capacity to do so (Berkes and Jolly 2001; Newton et al. 2005). Thus Riedlinger (1999) argues that concentrating exclusively on what science has to offer 'may limit our understanding' of climate change and its impacts at local levels.

Yet no generalisations can be made about the spread in the use of IK in climate related issues. While pastoralists in southern Ethiopia and northern Kenya still widely employ an extraordinary variety of indigenous forecasting methods like observing clouds, stars, wind, lightening and the behaviour of animals, and had ex ante confidence and ex post perception of forecast accuracy (Luseno et al. 2003), studies in Burkina Faso (Roncoli et al. 2000), and in Lesotho (Ziervogel 2001; Ziervogel and Downing 2004) show that local forecasting knowledge seems to be less widely used than in the past. Luseno et al. (2003) attributed the high confidence to the wide variety of indigenous forecasting methods that the pastoralists use: the focus on climatic features of interest to the pastoralists like the onset of rains, the small spatial resolution of the indigenous forecasts, their communication in local languages by recognised 'local experts' in the community and the accessibility of the indigenous forecasts compared to the forecasts by the meteorological agencies.

In contrast, the reduced use of local forecasting knowledge in Burkina Faso (Roncoli et al. 2000), and in Lesotho (Ziervogel 2001; Ziervogel and Downing 2004) were attributed to increased climate variability that have led to less consistency between indicators and outcomes, and the changing social environments that no longer always place much emphasis on traditional beliefs as in the past (Roncoli et al. 2000; Ziervogel and Downing 2004). As a result, farmers were also showing interest in how they might be able to use seasonal meteorological forecasts.

The question then is whether and how people use IK to adapt to climate variability and change. Roncoli et al. (2002a, b) analysed farmers' responses to seasonal rainfall forecasts in Burkina Faso and found that most responses are minor modifications to a highly diversified and risk-averse production system rather than drastic changes that seek to maximize yields or profits. Roncoli et al. (2002a) noted that it is difficult to identify causal links between forecasts and behavioural outcomes as many factors influence farming decisions. They found that pastoralists do not use forecasts to support livestock management decisions because they make their decisions based on outcomes of rains rather than forecasts of rain. Lemos et al. (2002, p. 497) analysed the use of seasonal climate forecasts by farmers in northeastern Brazil and report that farmers, despite reading and interpreting traditional indicators of an upcoming season, do not significantly alter their cropping practices as they continue to rely on 'age-old growing technologies designed to spread risk and maximize production'. The authors report that farmers 'have much more faith in Nature, being under God's control, than they do in science'.

Studies show that irrespective of the quality and precision of the forecasts (IK-based and meteorology-based) that several socioeconomic, political and cultural factors constrain the ability of actors to respond and adapt to forecasts (Lemos et al. 2002; Roncoli et al. 2002a, b; Luseno et al. 2003). Due to the high vulnerability of actors to climate variability, in terms of poverty, and lack of resources, actors have a limited range of choices to adapt their strategies. Thus, Lemos et al. (2002) conclude that the impacts of forecasts will remain insignificant among the farmers until their levels of structural vulnerability (lack of assets, resources, or ability to choose) are permanently reduced.

Against this background, this paper analyses the IK, which agro-pastoralists in the semi-arid areas of the larger Makueni district (now Makueni, Mbooni, Kibwezi, Nzaui districts), Kenya, hold and how they use this knowledge to monitor, mitigate and adapt to drought, one form of climate variability that is common in the semi-arid climates. Through various lead questions we attempt to elucidate the value of IK for climate change research. We examine whether agro-pastoralists actively use their IK on indicators of drought to adapt their practices or not, the reasons why and the implications for climate change monitoring, mitigation, adaptation and policy.

1.1 The study area

The former Makueni district (Fig. 1) lies between latitude 1°35′ S and 3° S and longitude 37°10′ E and 38°30′ E, and is located in the south-eastern part of Kenya

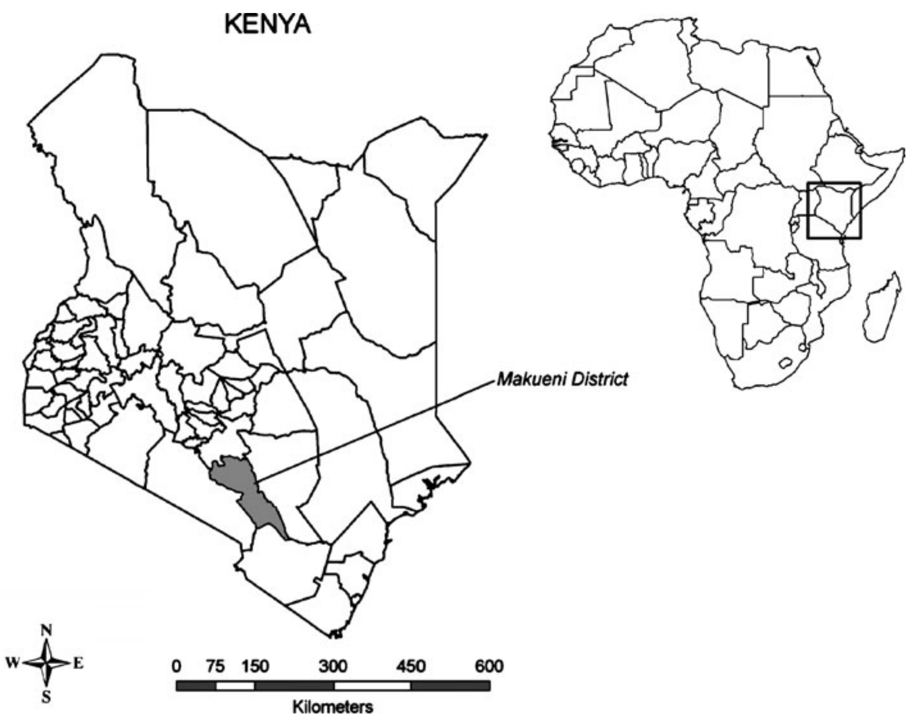

Fig. 1 The Makueni District study area in Kenyan and African context

with Nairobi to the northwest and Mombasa to the southeast. The majority of the rural adults are agro-pastoralists who depend on rain-fed agriculture and livestock keeping. The district covers an area of 7,965.8 km^2 out of which the semi-arid area comprises about 63%. The semi-arid areas are characterised by sparse vegetation cover and soils of low to medium fertility.

The climate of East Africa is mainly influenced by monsoons, the inter-tropical convergence zone (ITCZ), subtropical anticyclones, African jet streams, and easterly/westerly wave perturbations, teleconnections with globalscale systems like the El Niño/Southern Oscillation (ENSO) and regional systems (Ogallo 1989, 1994; Kabanda and Jury 1999). The southward and northward movement of the ITCZ is associated with the bimodal rainfall regime of the study area: the first rainfall season is in March–April–May (MAM) also referred to as the "long rains" and the second season occurs in October–November–December (OND) otherwise known as the "short rains".

Rainfall is highly variable, in amounts, space and time and droughts are recurrent. Droughts and floods are mainly attributed to the ENSO, tropical cyclone activity and anomalies in monsoon wind systems (Ambenje 2000). According to the IPCC (2007, p. 945), 'El Niño and La Niña describe the warm- and cold-phases of the tropical Pacific Ocean east of the dateline, respectively. They are associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. These coupled atmosphere-ocean phenomenon that mainly have timescales of 2 to about 7 years is collectively termed the EL Niño/Southern Oscillation (ENSO). During a warm ENSO event, the trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds'. The reverse is experienced during a cold ENSO event. In East Africa, ENSO influences the ITCZ, regional monsoon wind circulation and causes rainfall anomalies (Ambenje 2000). El-Niño events are often associated with above-normal rainfall conditions over the equatorial parts of eastern Africa during the OND while La Nina events are associated with below-normal rainfall. According to Ambenje (2000) El Niño episodes at times suddenly change to La Niña conditions and vice-versa. When such reversals occur, many locations with strong ENSO signal experience severe floods (e.g. heavy rains associated with the 1997–98 El Niño event) that are followed by severe droughts (e.g. the 1998–1999–2000 La Niña associated dry conditions).

Tropical cyclone activity over southern and north-western Indian Ocean regions also affects rainfall conditions in equatorial East Africa. Cyclones are associated with intensive rainfall over the region of occurrence, but they can cause drought in the regions outside the cyclone activity by dragging/accelerating the normal winds to the cyclone region. This is one of the factors that caused the failure of the MAM 2000 rainfall season in the tropical eastern Africa region (Ambenje 2000).

Written records found on drought in the study area go back to as far as 1836. Major droughts in the study area occurred in 1897, 1943, 1960–1962, 1965, 1971–1975, 1982–1984, 1999/2000, 2003, 2005/2006. The droughts are so frequent that hardly have the agro-pastoralists recovered than they have to face the next drought. These droughts occur on the backdrop of widespread poverty and limited access to resources, which further compromise agro-pastoral capacities to adapt to and recover from drought.

2 Methods

The study was carried out under a larger project focussing on livelihood security, drought vulnerability and risk in agro-pastoral areas. The data were collected in a longitudinal survey between 2001 and 2004 comprising interviews of key persons, questionnaire administration to 127 households in eight villages, workshops and group discussions (cf. CETRAD 2004). The focus persons for the questionnaire administration were the household heads (male or female). Special individual interviews with focus on IK and rainfall variability among agro-pastoralists older than 50 years were used to collect additional data because it became evident during the group discussions and the interviews that IK is not general knowledge but is related to the length of time a person has been living in an area, direct experience and the socio-cultural embedment of the persons. The older persons (50 or above) were found to capture these two variables—long-term direct experience and socio-cultural embedment—thus the special interviews targeted them to collect additional data which might not have been captured using other methods. In addition to questions relating to IK which were administered to the household heads, the target group (age 50+) was also asked questions relating to historical timelines of the villages. Daily rainfall data of three stations covering the period 1961 to 2003 were also analysed while the 1999/2000 drought is used as an entry point for the analysis.

The statistical results presented in the following sections are mainly from multiple response frames. Therefore the total of the responses can be more than 100%. It is important to note that the information presented in this paper on IK are as accounted by the respondents and have not been verified by the authors for their validity, for example as indicators. As such we cannot say that the indicators are correct or false. We are only documenting the IK, which the local actors have on drought and non-drought conditions. The local names are in *Kikamba* language.

3 Results

3.1 Agro-pastoralists' perceptions of drought and IK

Agro-pastoralists' knowledge and perception of drought can influence their strategies to reduce their vulnerability to drought and, in a wider sense, to adverse climate change. Examining individual knowledge and perceptions is crucial for understanding why certain actions among agro-pastoralists differ. Ninety-nine per cent of the respondents regard drought as lack of rains (while 1% did not provide any explanation), but 50% further distinguish drought as a prolonged period of at least two seasons without rainfall. This means that for the agro-pastoralists, 'duration' is also an important factor for defining drought, just as it is for some scientific definitions. However, the actual duration of meteorological drought and its impacts on crops are not the only major drought-defining factor for the households but also the 'duration' within which they can manage with drought and recover from its impacts.

In a multiple response frame, a majority of the respondents (69%) attributed drought to God's wish to punish mankind (Table 1). Other causes given were the lack

Table 1 Agro-pastoralists' opinions on causes of drought

Causes of drought	Percent
God's wish to punish mankind	69
Lack of trees due to deforestation	21
Changes in weather patterns and conditions	12
Lack of hills, water masses and mountains	4
Failure to sacrifice traditionally	4
Witchcraft	2
Misuse of shrines and sacred areas	2

of trees due to deforestation (and subsequent lack of reforestation), and changes in weather patterns and conditions. Less than 5% attributed drought to lack of hills, water masses and mountains, failure to sacrifice traditionally, witchcraft, and the misuse of shrines and sacred areas. Worthy of note is that 25% of the respondents attribute drought to environmental causes (Table 1).

The frequency of drought changes the decision frameworks for agro-pastoralists and can influence agro-pastoralists' strategies and actions. While 54% of the households perceive that drought has no pattern of occurrence (Table 2), 45% believe that there is some periodicity in drought occurrence and 1% had no idea. However, the periodicities provided vary (Table 2).

In order to put the 1999/2000 drought in context of other droughts in the study area, agro-pastoralists perspective of the 1999/2000 drought is examined. The 1999/2000 drought refers to the seasons in 1999 and 2000 which were affected by drought (rainfall deficit; rainfall below normal) and which are collectively referred to as one drought (based on both its climatological and socioeconomic spread) by using the term 1999/2000 drought. Eighty-five per cent of the households rated the 1999/2000 drought as a mild drought. This is contrary to findings from rainfall data analyses wherein the 1999/2000 drought was one of the most severe since many years (Ifejika Speranza 2006, p. 220–222): The analyses of daily rainfall records for Makindu station, showed that the MAM-rains in 1999 had a severe drought, the OND-rains in 1999/2000 had a mild drought, while the MAM-rains in 2000 had a severe drought. Similar results were obtained for Kibwezi and Ikoyo stations. Only 5% and 8% of the agro-pastoralists perceived the drought to be severe and very severe, respectively. This divergence can be explained by the fact that

Table 2 Agro-pastoralists' opinion on drought periodicity

Periodicity in drought occurrence	Periodicity	Respondents (%)
Yes (45%)	Every 2 years	14
	After 1 year	9
	Every 10 years	9
	Every 3 years	8
	Every season (two times a year)	5
No (54%)		
No idea (1%)		

agro-pastoralists perceive drought both in climatological and socioeconomic terms: climatologically in terms of rainfall deficiencies and socioeconomically in terms of the contextual conditions and the period during which drought impacts are experienced. The respondents explained that the 1999/2000 drought was a light drought because there was some little harvest (32%), relief food was available (22%), there was also food to buy in the markets (21%), and some households still had food from previous harvests (16%). This perceived 'mildness' can also be interpreted from the aspect of the 1997/98 abundant El Niño-related rains and resulting bumper harvest. Those that rated the drought as severe or very severe mainly lost their harvests (10%). Other minor reasons like illness or lateness to plant are non-drought in character.

3.2 IK and drought monitoring

Agro-pastoralists usually derive IK-based forecasts for an upcoming season just before the beginning of the farming season. As the season progresses they acquire additional information through direct observations but can complement this by consulting other local sources. The Kenya Meteorological Department (KMD) gives out a three-month seasonal outlook in newspapers, on radio and television, just before the beginning of the farming season. The media also broadcast short-term daily weather forecasts prepared by the KMD.

Thus many holders of IK also have access to other forms of knowledge or information sources. However, 28% find IK to be reliable and do not consult any other sources. In addition to IK forecasts, 5% consult diviners, 16% have IK forecasts but believe that a season is God-given and as such do not see the need to consult any other sources of information. Twenty-nine percent listen to seasonal outlooks and daily weather forecasts by the KMD on radio in addition to the IK that they have and 1% in addition give money to old people to sacrifice. These proportions can vary depending on actual circumstances of an upcoming season.

While 77% of the respondents hold IK on diverse indicators of drought, 13% believe that there are no signs that can be used to forecast drought and 10% do not take a position. The signs mentioned can be broadly grouped into indicators from fauna (37%), from local weather conditions (36%), rainfall amount and patterns (22%), flora (20%), astrological constellations (11%) and the local physical environment (4%). The details are displayed in Table 3. Most (60%), out of the 77% that hold IK on drought indicators, also find them reliable (Table 4). The reader should note that where existing, the Latin or common English names of the local *Kikamba* names are provided.

The measures of reliability are based on respondents' experiences of failure of these indicators. Agro-pastoralists that rate the signs to be unreliable have experienced non-drought conditions despite observing drought indicators; agro-pastoralists that regard it to be fairly reliable have in about a third of the cases experienced non-drought conditions despite observing indicators of drought. Those agro-pastoralists that regard the indicators to be reliable, (35%) have experienced drought as forecasted by the drought indicators to occur most of the time while those that regard the indicators to be very reliable have never experienced the indicators to fail. Worthy of note is that the few respondents that regard IK-based indicators as being unreliable or fairly reliable refer to weather indicators and indicators derived

Table 3 Indicators used by households to foretell the likelihood of drought

Indicators of drought	Percent of cases	Broad classes (%)
Has no idea/cannot tell/no signs/explanation not clear	24	
Animals, birds and insect behaviour/signs		37
Poultry, cattle and human beings look weak all the time	10	
Movement/migration of bees/birds from west to east; south to north in search of water	8	
Appearance of rare birds/insects	8	
Millipedes (*Syomutitu*), *Kaunga* birds, crickets making noise at night	5	
Appearance of certain ants (e.g. *Muthua, Nduti*)	2	
Invasion of wild animals in the area (e.g. zebras)	1	
Presence of too much honey in the hives indicates that the next season will be affected by drought	1	
Frogs fail to make noise	1	
Disappearance of certain birds/insect species (e.g. weaver birds)	1	
Local weather conditions and signs		36
Presence of mist during the dry season	8	
When the sky is very clear	8	
When it is very sunny and hot	6	
Very strong wind blowing	6	
Unusual coldness/low temperatures	5	
Appearance of nimbus clouds at daytime and disappearance at night	2	
Presence of dew in the morning	1	
Rainfall patterns and amounts		22
Rains delay for a long time (between 2 weeks and one month)	12	
Low rain falls at the beginning of a farming season/irregular rains	8	
A lot of thunderstorms during onset of rains	1	
Lightening becomes rare	1	
Signs from flora		20
Trees fail to flower or blossom late (*Acacia sp., Muthiia, Mwa*)	8	
If certain trees (*Acacia, Muthiia, Maulu, Baobab*) blossom too much the next season will be affected by drought	6	
Tree leaves turn yellow/shed leaves (*Maulu, Kiwua Nzuki*, *Yiulu* trees)	3	
Flowering of *Muvau, Kinguthi, Maulu* trees	3	
Astrological constellations/signs		11
Sky is full of stars at night	4	
The size and shape of the moon	3	
A very small circle around the sun and no circle around the moon	1	
A constellation of 7 stars appear in the East	1	
When the sun passes to the left of the Capricorn/ The position of the sun	1	
No shading of the sun	1	
Signs from the local environment		4
Water masses dry up earlier than usual	2	
The shadow of Maluini hills changes the normal position	1	
When Mt. Kilimanjaro looks clear for a long time	1	
Calendar readings		1
Every year ending with 3 or 4 e.g.1983, 1994 etc.	1	

Table 4 Agro-pastoralists' opinions on reliability of indicators derived from IK

Have IK on drought indicators	Reliability of indicators from IK	Respondents (%)
Yes (77%)	No idea	8
	Not reliable	9
	Fairly reliable	2
	Reliable	35
	Very reliable	23
No (13%)		
Unsure (10%)		

from rainfall patterns and amounts. But a larger proportion (77%) of weather indicators, indicators from rainfall patterns and amounts (88%), animals and insect behaviour signs (93%), indicators from flora (89%), from astrological constellations (89%) and from the local environment (100%) are experienced to be reliable and very reliable.

Agro-pastoralists also use the same signs from local weather patterns, state of flora and fauna, constellation of stars as well as features from the physical environment, such as the amount of snow on Mt. Kilimanjaro, to forecast the nature of rains in a season (Table 5). However there is no significant difference in preparedness actions between those that regard the drought or non-drought signs to be reliable and those that do not.

In the case of forecasting non-drought seasons, indicators from local weather conditions and rainfall patterns dominate (Table 5). IK indicators from local weather range from temperature, humidity and wind conditions, the presence or absence of certain types of clouds, rainfall patterns and amounts. These weather indicators are also used in formal climate monitoring. Although local people do not measure and record climatic data like in formal climate monitoring, through observation based on life long experience in their area, they can predict the average onset dates for rainfall, and a delay in onset for them is already an indicator that the season might not bring adequate rainfall.

From Tables 3 and 5 we see that IK indicators can be in terms of unusual conditions like appearance and disappearance of certain animals, birds and insects. Indicators are also derived from animal or insect behaviours—insects making certain noises, bees migrating. The appearance of certain birds (e.g. *Ngoso* birds (sparrow weaver); Latin name: *Plocepasser mahali melanorhynchus*), and the disappearance of others like weaver birds (Latin name: *Ploceus nigricollis malanoxanthus*) indicate drought (Table 3). The migration and direction of migration of birds and bees (depending on locality from east to west, west to east or south to north) indicates drought. The actors interpret that the bees are migrating to areas with rainfall (water). The invasion of certain ants (*Muthua*; Latin name: inexistent/not found, *Nduti*; Latin name: inexistent/not found), wild animals (e.g. Zebras and *Ilonga* (gazelle); Latin name: *Gazzelle*), and birds indicate drought. The making of certain noises by millipedes, crickets at night and by certain birds (e.g. *Kakunga;* Latin name: inexistent/not found) also indicate drought. The actors interpret the conditions and behaviour of domestic animals such as poultry and cattle 'looking hungry all the time and fighting over food' as indicators of drought, while too much honey in the beehives indicate that the following season will have less rains.

Table 5 Indicators used by households to foretell that a season will not be affected by drought

Indicators of a non-drought season	Percent of Cases	Broad classes (%)
Has no idea/cannot tell/no signs/explanation not clear	13	13
Animals, birds and insect behaviour/signs		15
Movement of bees/birds (e.g. Malwe) from east to west, north to south etc.	5	
Appearance of many birds in groups (*Nthungululu, Nzonzwe*)	5	
Many wild animals (*Mbaa*, squirrels, *Nganga* birds) attacking germinating crops	3	
Appearance of dragon flies/butterflies/other insects	2	
Local weather conditions and signs		37
High temperatures before/after the rains	13	
Appearance of nimbus/cumulus/dark/small/few clouds on the sky	12	
Cool atmosphere	9	
Cloudy sky	1	
Strong winds at the start of rains	1	
Before the rains, wind blows from Mt. Kilimanjaro and back	1	
Rainfall patterns and amounts		77
Rains start at the expected time	30	
Rains fall at night/at regular intervals of days/months	23	
Heavy downpour prior to actual rains	11	
Adequate rainfall (author's comment: an outcome indicator)	6	
Thunderstorms are experienced	4	
Lightening shows adequate rainfall at the beginning of a farming season	1	
Rains coming from Mt. Kilimanjaro, other directions are unusual	1	
Rains are not heavy	1	
Signs from flora		19
Flowering of trees e.g. *Acacia* sp., *Kithumula, Mumbu, Baobab, Kithiia, Mataa Mwaka, Kiatine, Kiusi, Kiua, Nyumbililya, Ikuyu, Siunga,* mango trees	15	
Ripening of *Thwaala*	1	
Adequate pastures (authors' comment: an outcome indicator)	1	
Unusual shedding of the flowers of the mango tree	1	
Flowering of *Muthiia* tree before onset of rains	1	
Astrological constellations/signs		11
Appearance of a circle/circles around the moon/the sun	5	
Few stars in the sky	3	
Shading of the sun	1	
The moon moves from one direction to the other	1	
A constellation of 7 stars (*Kiemea*) remains at a central position	1	
Signs from the local environment		
Good harvest	5	5
A general feeling of well-being	4	4
Mt. Kilimanjaro looks very dark	1	1
No abnormal events like locust invasion	1	**1**

In terms of an upcoming non-drought season (Table 5), certain birds (e.g. *Nthungululu*; Latin name: Swifts/sparrows, *Mithonzwe*; Latin name: inexistent/not found), become common, while wild animals (e.g. *Mbaa* (yellow necked spur fowl) Latin name: *Francolinus leucoscepus*, squirrels, *Dik diks*) attack germinating crops. The migratory patterns change (depending on locality), instead of the bees and birds migrating from east to west or north to south, they move from west to east or south to north.

Drought indicators (Table 3) from flora can be in terms of tree conditions, unusual flowering of certain trees (e.g. *Kinguthe*; Latin name: *Lonchocarpus sp. sterile*, *Muvau*; Latin name: *Dombeya burgessiae/kirkii/rotundifolia*, *Maulu*; Latin name: *Commiphora sp. sterile*), non-flowering (e.g. *Acacia* sp. trees, *Muthiia*; Latin name: *Acacia mellifera, Mwaa*; Latin name: *Acacia tortilis*), flowering too little or too much. According to the respondents, if *Acacia* sp., and *Muthiia* trees flower a lot or Baobab (*Kiamba*, Latin name: *Adonsonia digitata*) and *Kasivu* (Latin name: *Boscia coricea*) trees produce many fruits (unusual production) then the following season will be affected by drought. Indicators can also be in form of timing, for example, the late flowering of *Acacia* sp. and *Itula* trees (Latin name: *Commiphora holtiziana/baluensis*) in November instead of October indicates drought, or the early shedding of leaves (e.g. *Maulu/Yiulu*; Latin name: *Commiphora sp. sterile*, *and Kiwua Nzuki*; Latin name: inexistent/not found). However, there are variations and nuances in variations, which are interpreted differently. For example pertaining to *Mataa Mwaka* (direct translation means seasonal weather advisor, meaning rains can start any time); Latin name: inexistent/not found. According to one respondent, '*Mataa Mwaka* tree flowers to indicate the end of a dry season, and the onset of rains should be experienced before the flowers wither,…if the flowers wither before the onset of rains just know that there will be insufficient rainfall'. Among the Kikamba, the flowering of *Mataa Mwaka* indicates the rains are just about to start; can start any time once the flowers are spotted. Flowering of certain trees indicate non-drought conditions while the non-flowering of the same trees can indicate drought conditions (Tables 3 and 5). However, the actors interpret an above average production (flowers and fruits) as an indicator that the following season will be affected by drought. These nuances in differences need further studies to better capture the nature of the indicators.

Astrological constellations, such as the position of the sun and moon are also interpreted for the upcoming season. Other features from the environment used to forecast rains or drought in an upcoming season include the shadow of the local hills and the clear sighting of Mount Kilimanjaro more than 100 km away.

3.3 IK and drought mitigation

Understanding the degree to which local people perceive drought risk and vulnerability to be controllable or preventable is crucial for designing mitigation measures on ways to reduce vulnerability to drought. The information in Table 6 shows that 45% regard drought to be God's plan, therefore it cannot be reduced. Eighteen per cent had no idea how drought can be reduced. However, about a quarter of the respondents expect that humans can reduce drought through environmental measures like planting trees, reducing deforestation, protecting forests and avoiding air pollution. This relates to mitigation in the sense used by the IPCC as a reduction of GHG-emissions. Further, the respondents propose to increase water sources as a way of reducing drought. This rather relates to adaptation as used in climate-related literature but it shows that agro-pastoralists in the study area perceive drought not

Table 6 Respondent opinions on ways through which drought can be reduced

Ways of reducing drought	Respondents (%)
God's plan, cannot be reduced	45
Planting trees, reduce deforestation, conserve forests	24
No idea	18
Increase water sources	35
Prayers and offering sacrifices	11
Reduce witchcraft	1
Avoid air pollution	1

only in meteorological terms but also in terms of its impacts (e.g. reduced water availability) and thus regard mitigation and adaptation as complementary ways of reducing drought and its impacts.

3.4 IK and adaptive strategies

Agro-pastoralists are likely to alter their practices if they have prior knowledge of an upcoming drought or flood. As a common practice, 36% consult various sources for forecasts on the next season while 64% do not. Only 29% of the households sourced prior information on the likely occurrence of the 1999/2000 drought. Out of those who had foreknowledge of the likely occurrence of drought (29%), 7% did not do any thing about it while 22% adapted their strategies in anticipation of drought times ahead, by planting drought resistant crops and seeds, planting early maturing crops, and by stopping to sell their stored grains and saving money. Within this 22% is 16% that hold IK and believe that it is reliable. Although the proportion of households that consult seasonal forecasts is low (29%), the fact that 22% consulted and actually acted on the predictions by implementing actions to reduce their vulnerability is noteworthy in the context of widespread poverty. If the practice to access information on the likelihood of drought occurrence is taken as a proxy for drought preparedness, the foregoing shows that only about one third of the households source this information, others respond to drought as and when it occurs (Ifejika Speranza et al. 2008).

3.5 IK as preserved in names given to famines triggered by climatic events

Apart from their meteorological nature, drought and floods also have various social dimensions. An interesting feature of droughts and floods in the study area is that people characterise them according to their intensities and major impacts, the responses to reduce the impacts of a particular drought or flood or the contextual specificities surrounding their occurrence. These characterisations highlight how climate hazards affect livelihoods; the coping and response strategies adopted to reduce their impacts; the nature of interventions by the government and others; and how society perceives the response activities and their effectiveness. The names (aliases) of these climate-related events reveal the varying contextual dimensions of their occurrences and provide further information for drought and flood assessments.

In the following, a few events have been selected to describe the stories that the names tell (Box 1):

Box 1: Names of climate related events

1897:	*Yua ya Lwaya* (Translation: Named after a disease epidemic (believed to have been rinderpest) that killed livestock (cows) in large numbers) – Failure of three consecutive rains, rinderpest occurrence, locusts' invasion and human deaths.
1961:	*Yua ya mafuriko*, *na ndeke* (Translation: Famine of floods and aeroplanes) – This period was characterised by floods in the short rains preceded by droughts in the long rains. The local names indicate that due to floods, food aid had to be dropped by aeroplanes to the affected areas.
1965:	*Yua ya Atta* (Translation: Famine of brown wheat flour) – Many people were eating brown wheat flour (known as Atta) to survive as there was no other food available.
1982–84:	*Yua ya nikw'a ngwete* (Translation: I am dying with cash in my hands/pocket; Famine with cash in my pocket but nothing to buy) – In addition to harvest losses caused by drought there was a simultaneous market failure. Despite having money people could not buy food in the markets due to the high prices and the low supply of food to the markets.
1984:	*Yua ya katokelele* (Translation: The famine of yellow maize) – There was severe drought. Yellow maize donated or imported from the North/West was distributed to people as relief food, but because yellow maize is perceived as food for livestock, many attempted to sell their rations of yellow maize to buy what they deemed food for humans. The markets were thus flooded with yellow maize that very few people bought.
2005 – 2006:	*Ndyaaona ou* (Translation: I have never seen such a condition before) – Athi River, a major perennial river, dried up along some stretches. This was very unusual for the inhabitants of the area, hence the name. Meteorologically, the 2005/06 drought was very severe (Oludhe et al. 2006) prompting the Kenyan government to declare it a national disaster and supporting relief food distribution in the northern and eastern parts of the country.

4 Discussions

4.1 IK in drought monitoring and impact assessment

Of what use then are IK-based indicators for rainfall variability monitoring and impact assessment and in a wider sense for climate change monitoring? Almost 80% of the households use IK indicators for upcoming drought-affected or non-drought seasons. Most actors (58%) believe in their reliability. Those households that have access to the mass media (such as radio) consult seasonal forecasts (outlook) broadcast by the KMD in addition to using IK. Others verify indicators from IK by consulting traditional seers and diviners for forecasts for the upcoming season. There are also others that believe in the reliability of IK indicators but regard the indicators as being under the influence of God as they believe that a season is God-given. Another group believes in the reliability of the IK indicators and does not source further information. Thus, the agro-pastoralists seem to use IK as background knowledge, or a 'knowledge frame', within which other sources of information are positioned and interpreted. These findings correspond with those of other studies on IK in other areas (Hammer et al. 2001; Luseno et al. 2003).

The names that local actors gave to famines triggered by climatic events (see Box 1) signify the main distinguishing character of the event, and to a great extent, reflect the severity of the climatic events in meteorological and socioeconomic terms. In some cases the names also relate to general scientific findings. For example, the name given to the drought of 1982–84 (see Box 1) clearly relates to A. Sen's work (Sen 1981) on entitlement and development. First there was production-based entitlement failure due to decline in food production as a result of drought. However, people did not suffer lack of cash endowments as they had "money in their pockets but no food to buy" since there was widespread food supply decline in the markets nationally (market failure). This prompted the government and international donors (e.g. USAID) to provide food aid and influenced institutional reforms leading to the establishment of the national strategic food reserves planned to last for at least 6 months, and managed by the National Cereals and Produce Board. Since there can be many causes of famines, the explanation given here does not refute other explanations of famine like "exchange entitlement failures" (cf. Sen 1981; Devereux 2001). Thus, this local knowledge contributes to the understanding of issues related to climate variability and change.

The persisting IK of agro-pastoralists on climate indicators implies that many agro-pastoralists still continuously monitor their environment for changes. IK can thus complement 'scientific modes' of climate monitoring which are mainly carried out at regional and global scales and so do not (yet) take adequate account of variations at micro-levels.

However, agro-pastoralists' perception of drought, that is, the process of attaining awareness about drought, depends on other framing conditions like the availability of food in the markets, household food storage and availability of relief food. It also depends on adaptive capacities and how effective the adaptation strategies are. This implies that non-drought factors also shape how the local people determine onset, duration and end of drought. Thus, IK-based indicators are one of the many factors considered in decision-making by the local actors.

4.2 IK and adaptive strategies

Do agro-pastoralists adapt their practices based on indicators from IK in order to reduce their vulnerability to drought? The answer is not a no or a yes: The value of IK-indicators for agro-pastoralists cannot only be judged by whether they act on them but also on whether they acknowledge these indicators. Agro-pastoralists incorporate indicators from IK and their experience of 'variable rainfall conditions as the norm' into their decision-making framework. The low number of actors that adopt anticipatory measures with respect to a predicted drought (whether from IK, radio forecasts or other sources) reflects that although important, IK is only but one of the many factors which influence local actors' decisions on whether to prepare for drought or not. Despite their knowledge in IK, and belief in the reliability of the IK indicators, several factors beyond their control limit the range of adaptive actions they can take (cf. Dixon 2001; Lemos et al. 2002; Phillips et al. 2002; Roncoli et al. 2002a; Luseno et al. 2003). Poverty and deteriorating access to livelihoods and other resources strongly determine actors' capacities to take preventive measures against drought impacts and to reduce their vulnerability. Indeed only less than one third of them in the study area could take any adaptive measures against the foreseen impacts of the 1999/2000 drought. As a result many agro-pastoralists' decisions regarding adverse rainfall variability are of a contingent and reactive nature rather than proactive. This is particularly so for the OND-rains, which are regarded to be more reliable (less variable) than the MAM-rains that are more erratic in the study area. Based on this experience-based knowledge that the MAM rains are erratic and unreliable, agro-pastoralists generally reduce the amount of inputs—e.g. cropped area, seeds, labour—used in the MAM-season.

Can the identified IK work under future climate change conditions? We find that the effectiveness of the identified IK indicators might be limited under future climate conditions. This is because those IKs that are derived from biotic resources (flora and fauna) may become modified or change completely because the biotic resources also adapt themselves to changing climatic conditions while some biotic resources may even become extinct (cf. Boko et al. 2007, p. 435). Further, (1) very few people's IK is in-depth and those people that have this knowledge are dying out. IK is no longer systematically passed directly to the next generations as was the case in the past traditional systems; (2) IK is not incorporated into current curriculum and even then as second-hand knowledge because people do not experience it themselves; and (3) as climate changes, the physiology of the plants are expected to change as a way of adapting to new ecological conditions. Thus the future use of biotic objects for climate change monitoring is limited. On the other hand, IK derived from climatic variables like temperature, wind direction, rainfall amounts and patterns can still provide valuable information on climate change but these indicators require continuous monitoring as they also change. However, IK may not remain static because with gradual climate change local people may with time identify new local indicators. In terms of how best to integrate IK in the development of adaptation plans, there is need to change the attitudes of especially the educated people about IK, and to disseminate IK to a broader audience by giving it a platform. As in many African societies (cf. Dube and Sekhwela 2008) traditional institutional frameworks provided for management of resources in ways that helped buffer climate impacts in the study area. Where still viable, these traditional frameworks need to be revitalised and allowed their place in local decision making and management.

4.3 IK, climate change research and policy

What difference can IK make in the quality of climate change research and policy? IK has been, and continues to be, used for climate monitoring. We see the roles of IK and climate change research as complementary. Since IK is place, time and culture specific, it can contribute to fill in gaps in terms of linking its micro-scale observations to the macro scale frames of climate change research. Since IK is culture-specific, insights can be gained on how forecast information can be adapted to fit the local audience; and furthermore, linking IK to science would provide an avenue to involve local people in climate change monitoring. Additionally, since IK is a different form of knowledge, it can highlight other aspects of climate monitoring, which may have gone unnoticed, or given inadequate attention in 'western' science. A further question is how can IK contribute to triggering adaptive practices? Since non-environmental factors drive to a large extent the way actors adapt to drought conditions (Ifejika Speranza 2006), the trend is that IK may continue to be used mainly for monitoring, as findings in this paper suggest. For example, despite the IK that fallowing, zero tillage, agro-forestry, mulching, run-off harvesting and organic farming have advantageous effects for the environment, such practices are rather waning due to dynamic socio-political factors such as insecure land tenure and changing socioeconomic conditions, e.g. limited financial resources and labour.

Further, the continued widespread use of IK in monitoring is threatened by the limited transfer to the younger generation. Agro-pastoralists report that although they inform the younger generation about IK, the younger generation perceive IK as 'foreign' information and have less regard for the traditional systems. They report that the younger generation perceive IK as outdated and disassociate with traditional practices. Various reasons are behind this: Firstly, many of the older generation converted from the traditional religions to Christianity but they still retained their link to traditions (including IK), in some cases in an ambivalent way. Many of this older generation who still use IK grew up in Christianity where missionaries imbued them that anything related to tradition and traditional religion as is the case with IK, is unchristian and should be avoided. The younger people grew up within this context; some have formal education having been trained in the 'western' modes of science. Further, many of the younger generation cannot acquire IK directly through own long-term observation and direct experience because farming is no longer their only livelihood activity, so direct contact with the environment is not as much as among the older generation. This development can threaten the continued existence of IK as it is a form of knowledge that evolves not only through experience and practice but also through intergenerational transfer. Since 'western' science is the dominant form of knowledge, linking IK with formal climate monitoring can leverage the value of IK. This might rekindle the interests of the younger generation in IK as an important and independent form of knowledge.

Besides providing important indicators that can help to enrich or further inform, and possibly (re)direct formal climate change research at local levels, IK can also be used to develop policies on climate change monitoring, mitigation and adaptation: Sacred forests established under traditional legislations are known to have contributed to maintaining biodiversity and reducing land degradation in local watersheds. Since traditional legislation are generally waning, one way to continue this protective measure is for the modern State to support such traditions by declaring sacred forests protected areas. Further, IK highlights how climate change affects people at local level, an important aspect to inform policy changes especially with the aim to link IK with the national education curriculum, and foster collaboration between researchers and local actors in community based research partnerships. The latter can be a useful model for a platform to promote participatory pathways for addressing various climate change dimensions (cf. Berkes and Jolly 2001). The participation of IK-holders as local climate monitors for formal climate change monitoring can also increase the value of formal forecasts as many actors already find IK to be reliable.

5 Conclusion

This study demonstrates the richness of IK and the diversity of IK-based indicators for monitoring climate variability and -change. For example, various indicators from flora (*Acacia tortilis*), from fauna (weaver birds), from weather variables (temperature, wind direction), from astrology (constellation of stars), or even from the environment (the shadow of hills and the clear sighting of Mount Kilimanjaro more than 100 km away) provide a rich store of knowledge. Even though we did not compare the indicators with seasonal forecasts issued by the Kenya Meteorological Department, it is evident that this rich knowledge is yet to be fully utilised and combined with 'western' science.

However, it could not be established to which extent the various indicators, especially those based on biotic variables will remain valid as climate changes in the future. Yet the density of IK-based indicators used for climate monitoring has the potential to improve the coarse spatial resolution of meteorological forecasts, considering the sparse network of weather stations in Africa. To be able to harness IK for climate monitoring, the participation of the local actors is necessary as this knowledge belongs to them and they are the ones that use it. There is also need for hurry, because many who have this knowledge are dying out. Critical assessments of the contributions of IK to climate change research can be done through comparative case studies, through more detailed analysis of indicators (see for example Tables 3 and 5), by further documentation relating to climate as a whole, through long-term studies or comparison with empirical variables like temperature, humidity and wind direction which are used in IK, as well as in modern science. The ways in which these climate variables are used in IK can be compared with the scientific modes of using them.

The most important finding for implementing adaptation is that agro-pastoralists do not or are unable to change their practices in response to an IK-forecast of drought significantly, despite the richness of IK indicators and the high confidence that the actors have in them. Non-drought factors like poverty, inadequate resources and the conditioning of the actors to the high rainfall variability characteristic of the area and associated inappropriate attitudes limit the scope of choices they can make to reduce their vulnerability to drought proactively. These same factors: poverty, and inadequate resources of local actors to implement the desired strategies, also limit the role of IK to contribute to pathways to reduce the adverse effects of global change. Hence creating livelihood conditions that enable agro-pastoralists to respond to climate change by addressing the linkages between poverty and vulnerability is crucial for successful adaptation to climate change. We find that without addressing these constraints, forecasts, whether from IK or formal sources, may not trigger any significant adaptations to climate variability and -change by agro-pastoralists.

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