IMPROVED DROUGHT EARLY WARNING AND FORECASTING TO STRENGTHEN PREPAREDNESS AND ADAPTATION TO DROUGHTS IN AFRICA

DEWFORA

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Drought Vulnerability Assessment in Kenya

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SUMMARY

Assessing drought risk requires the assessment of both the hazard to drought, as well as the vulnerability of society to be affected by drought. A method for mapping Drought Vulnerability at different spatial scales that takes socio-economic indicators into account has been developed within DEWFORA (WP3 – 3.1 and WP3 – 3.2). Through this method relative vulnerability to drought can be established, supporting prioritisation of where measures such as drought warning should be targeted. The proposed method can be applied at a continental scale, as well as at a national scale. In this study, we apply the proposed method to Kenya, through which we assess the vulnerability at the county level.

The Drought Vulnerability Method includes the selection of socio-economic indicators to compute a Drought Vulnerability Index (DVI). The indicators chosen to calculate the DVI in this the study were selected based on expert judgment and available data, which was mostly obtained from government and public sources. The spatial resolution chosen was county level (the main administrative division within Kenya) as most of the data was available at this resolution.

The study shows the most important indicators for characterising vulnerability to drought in Kenya. The discussion arising from the correlation between the selected indicators and drought vulnerability, and the relevance of socio-economic indicators for determining drought vulnerability in Kenya is highlighted. Moreover, the study reflects the opinion of local Kenyan economists, sociologists, hydrologist, agronomist, and meteorologists on the method used.

Results show that at the county level Kenya has a heterogeneous distribution of drought vulnerability. Counties in the North-East, bordering Somalia are shown to be very vulnerable to drought. These include the counties of Wajir and Mandera, which are characterised by low incomes, low population, and low literacy percentages, as well as little rain. In contrast, other counties such as Nairobi or Lamu, present low vulnerability to drought.

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1. INTRODUCTION

Kenya suffers from extreme drought events as well as from extreme flood events. El Niño and La Niña are recurrent phenomena affecting the country and closely associated to the occurrence of these extreme events. Records since 1883 indicate that Kenya suffers from severe drought every 10 years. In some areas the return periods have become shorter in the last years, especially at basin and regional scale (Mogaka et al, 2006).

The consequences of droughts are disastrous. In Kenya, where agriculture is the largest employer, drought periods can result in a downfall of the economy. The last drought event took place in 2011 and 2012, creating a serious food crisis and resulted in 3.75 million Kenyans requiring food aid. Before that, in 1999 and 2000, another drought event considered as the worst in living memory was declared a national disaster.

Drought impacts include a reduction of crop harvests, loss of livestock, additional costs of livestock maintenance, reduced hydropower production, loss of incomes from industries, increase in the costs of vendor-supplied water in urban areas, increase of costs of desalination of groundwater in coastal areas, etc. The vulnerability of a country to drought is closely related to its social capacity, the strength of its economy, the dependency of its economy on the climate conditions, and its technological capacity to cope with drought impacts.

Drought vulnerability in Kenya has been previously studied by several authors (Campbell, 1984, Downing, 1989, Christiaensen et al., 2005, Chinwe et al, 2008). In most of these studies drought vulnerability is assessed from a physical perspective, focusing on the drought intensity and magnitude, and therefore in fact focusing on the hazard side of drought risk. Within DEWFORA we have defined a methodology to assess drought vulnerability (WP3 Deliverable 3.1, Iglesias, 2012) through establishing a Drought Vulnerability Index (DVI). The DVI is based on social-economic indicators, and has previously been applied at the continental scale based to identify the relative vulnerability to drought at the country level across Africa. In this study we apply the DVI at the national scale in Kenya, allowing the spatial distribution of vulnerability to drought within the country to be assessed.

1.1 STUDY AREA

Kenya lies in the Eastern coast of Africa. With a population of about 44 million and a surface of 581309 km^2, Kenya is the country with the largest Gross Domestic Product (GDP) in East and Central Africa (IMF, 2011). Kenya is bordered in the North East by Somalia, in the North by Ethiopia, in the North West by South Sudan, in the West by Uganda and Lake Victoria, in the South by Tanzania and in the East by the Indian Ocean. Due to its location at the Equator, Kenya has a tropical climate with constant temperatures around 22 degrees Celsius, and two rainy seasons from March to June and from October to December. However, the differences in orography and the influence of the Inter-Tropical Convergence Zone create a heterogeneous pattern of climates and precipitation throughout the country. Topographically Kenya has a great variation in elevation, ranging from the more than 5000 m.a.s.l. of Mount Kenya to the low lying areas in the East of the country and along the coast.

Kenya is administratively divided into 47 counties (see Figure 1.2). This administrative level was selected as the spatial scale in this study.

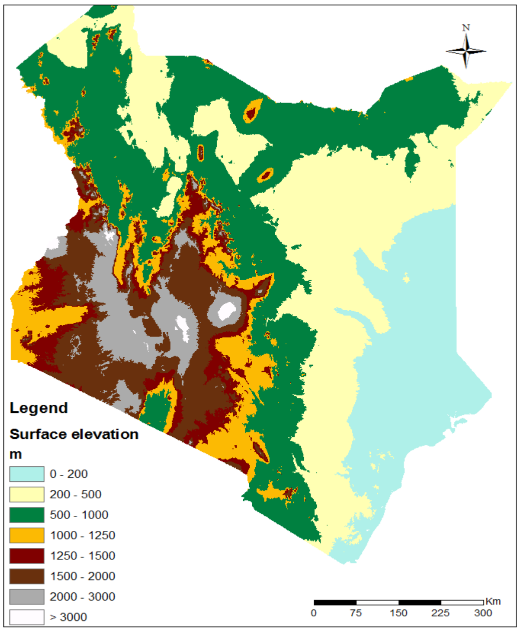

Figure 1.1 Location of Kenya (left) and surface elevation of Kenya (right)

Figure 1.2 Administrative division in counties of Kenya

2. METHODOLOGY

For this study on drought vulnerability in Kenya we adopted the method for mapping drought vulnerability at different spatial scales developed within WP3 of DEWFORA (Deliverable 3.1, Iglesias, 2012).

In the context of drought early warning, a focus on vulnerability may prove to be effective in determining where warning should be targeted since it includes the evaluation of the capacity to anticipate and compensate the adverse effects of drought. If a drought forecast is available, drought managers can gain time in responding and can develop an improved understanding of potential drought impacts. The focus on drought vulnerability requires the development of new drought indicators that are tailor made for a given drought impact. This requires information about the dependency of regional and local communities on water use. In addition to hydro-meteorological values, other variables that influence drought impacts are included in the analysis. This simplifies the difficult task of identifying threshold values of indicators at which drought problems arise. These threshold values can be used to trigger issuing of a drought warning, based on forecasts of impending drought conditions.

The capacity to adapt to drought or other hazards is implicit in the concept of sustainable development and implies economic as well as natural resource components. Adaptive capacity explains the system's capacity to anticipate, cope, and recover from drought. While the impact to society clearly depends on the intensity of drought, the response of society has – potentially – many social, human and environmental dimensions. However, adaptive capacity is difficult to measure and has to be represented by a combination of several variables. Crucial determinants of adaptive capacity are water policies and the projections of economic growth (Iglesias et al., 2007; Iglesias et a., 2011).

Within WP3 of DEWFORA a methodology to estimate an indicator of Adaptive Capacity to Drought (ACI) focusing on socioeconomic, natural and technological variables, and on their role in modifying drought impacts, especially for agricultural production and water resources is presented. The ACI evaluates the intrinsic characteristics of a certain system that define its response to drought. The ACI can be characterised in four major components; (i) social capacity, (ii) economic capacity, (iii) technological eco-efficiency, and, (iv) natural capital. There are two key challenges in the design of an ACI that is an adequate representation of the cause-effects relationship between drought and its impacts. These are the selection of the variables to be included in the ACI, and the weighting of each of the constituent variables. These two questions are ideally answered in the context of decision-oriented stakeholder and expert dialogues. Here we present an ACI that includes a large set of important variables from the theoretical point of view. The stakeholders in the case studies should select the most adequate variables and their weighting in each case.

Social capacity. Social characteristics depend to a large extent on the type of policies implemented in the country or region, ranging from self-sufficiency strategies based on market or protective policies for industrialised nations where agriculture only plays a marginal role. This component can be represented through some variables such as agricultural employment, which has a negative correlation to the overall adaptive capacity as a higher degree of agricultural employment implies a greater dependency of society on a highly variable sector. Other variables associated to this component include literacy rate, life expectancy and access to sanitized water, all of which are positively correlated to adaptive capacity because they imply healthier and stronger societies that can develop and implement solutions to adapt to drought in a more efficient manner. The evaluation of the effectiveness of institutional interaction and response are determinant for the implementation of potential measures to cope with drought.

Economic capacity. As in the previous case, the level of economic development is a variable of the capacity of a system to make investments in development technologies, food security and income stabilisation. The main variables considered in this component are related to GDP. In general GDP has a positive correlation to adaptive capacity, although the rate of agricultural GDP reflects a higher dependence on agriculture and, again, a lower adaptive capacity.

Technological eco-efficiency. Eco-efficiency significantly increases the adaptation potential of a system. The indicators selected include GDP per unit energy use, high technology exports and CO2 emissions per capita. Technological development of agriculture significantly decreases the dependency of this sector on climatic variables and stabilises production. This evolution is driven both by policies that aim for more productive crops or by private initiatives to increase the revenue from agriculture. The indicators selected for this component represent the technological advances applied to agricultural production. Therefore these indicators have a positive correlation with adaptive capacity, as these indicate the level of independence from climatic variability, including drought.

Natural capital. One of the most relevant threats imposed by drought is related to the water resource system resulting in increased water scarcity. Water management is related to climatic variability, but also depends on other factors, such as water resources infrastructure for water storage or transport, excess of demands or their mutual incompatibility, and constraints imports by water management policies. Policies related to the management of natural resources are crucial in developing early warning strategies. This component needs to incorporate information related to the variability of precipitation, which decreases the general adaptive capacity of a system as higher variability rainfall typically results in low efficiency of water resources infrastructure. In the case of agricultural systems, adaptive capacity also needs to include variables related to the use of water in this sector, such as irrigated water use or irrigated area. These two variables show positive correlation with the adaptive capacity because the more irrigated water is used in agriculture; the easier it is to stabilise agricultural production independent of annual precipitation or distribution, provided there is sufficient storage capacity.

The methodology proposed here is appropriate to integrate both quantitative and qualitative characterisations of adaptive capacity, thus permitting the involvement of the stakeholders in the process. The ACI can be applied locally or spatially and with different aggregation levels of the input data. The intermediate components can be evaluated independently, allowing comprehensive interpretation of the strengths and weaknesses of each system.
The sequential steps taken for the quantification of the ACI are: (a) select variables that are important; (b) normalize the variable values with respect to a common baseline; (c) combine the sub-component variables within each category by weighted averages; and (d) quantify the ACI as the weighted average of the components. The scores of the climate ACI range on a scale of 0 to 1, with the total being generated as the average of each component. The approach is flexible and can be applied to managed and natural ecosystems as well as to socio-economic systems.

The Adaptive Capacity Index (ACI) expresses the resilience of society to deal with drought. When the ACI is low, society is susceptible to being adversely impacted to drought, while this susceptibility is lower when society has the capacity to adapt, reflected through a high ACI. An alternative to the ACI is to express the susceptibility of society to drought through a Drought Vulnerability Indicator (DVI). This can be considered the reciprocal to the ACI, where a low DVI indicates that the susceptibility of society to being impacted by drought is low, while a high DVI indicates high susceptibility. In this paper we consider the ACI and DVI as interchangeable concepts, though logically ACI is positively oriented while DVI is negatively oriented.

2.1 SELECTION OF INDICATORS

The indicators used for establishing the adaptive capacity across Kenya were chosen based on expert judgment through consulting professionals from the University of Nairobi in the fields of meteorology, agriculture, hydrology, economy and social sciences. During a seminar where the methodology and available data were presented, the experts of the different fields discussed the most relevant indicators for the assessment of Drought Vulnerability in Kenya, and the correlation of those indicators with the vulnerability to drought.

Figure 2.1 Pictures of the workshop where experts discussed about the indicators for the DVI.

Table 1 shows a summary of the proposed indicators. In the next paragraphs we discuss the indicators individually as well as the correlation of each with drought vulnerability, their spatial and temporal resolution, and the limitations of their use in the computation of the DVI.

Table 1 Summary of the indicators used and their source

Social Capacity	
Indicator	Source
Population below poverty line	Kenya County Fact Sheets 2011
Total population	Kenya County Fact Sheets 2011
Literacy	Kenya County Fact Sheets 2011
Life expectancy	WHO, 2011
Population without access to improved water	Kenya County Fact Sheets 2011
Population without access to electricity	Kenya County Fact Sheets 2011
Public participation (voters)	Kenya County Fact Sheets 2011
Conflicts capacity	No data available
Access to roads and infrastructure	Kenya County Fact Sheets 2011
Access to information	No data available
Social networks	No data available
Economic Capacity	
Indicator	Source
GDP per Capita	UNDP2013
GDP per activity at constant prices	No data available
Agricultural GDP	UNDP 2013
Public expenditure	Kenya County Fact Sheets 2011
Areas of cropland	World Resources Institute
Livestock population	Kenya OpenData
Harvestable biomass	World Resources Institute
Tourists visiting National Parks	Kenya OpenData
Technological efficiency	
Indicator	Source
Fertiliser consumption	Kenya OpenData
Small-scale irrigation systems	World Resources Institute
Use of ICT technologies	No data
Use of appropriated and indigenous technologies	No data
Water harvesting and storage	No data
Natural capital	
Indicator	Source
Average precipitation	University of Nairobi, Meteorology Department
Water availability	Aquatast 2013

Total water use	Aquastat 2013
Agriculture water use	Aquastat 2013
Average water consumption of livestock	World Resources Institute
Average water consumption of wildlife	World Resources Institute

2.1.1 Social Capacity

<u>Indicator: Total population</u>

Data on population and number of households are obtained from the 2009 Kenya Population and Housing Census Report published in August 2010 by the Kenya National Bureau of Statistics. This indicator is given per county and it is positively correlated with vulnerability to drought.

<u>Indicator: Population below the poverty line</u>

The population below the poverty line is given per county (Kenya Count Fact Sheets, 2011) and is computed based on the Kenya Integrated Household Baseline Survey (KIHBS) district poverty estimates of 2005/06. County poverty rates are derived simply by dividing the total number of people below the Kenya poverty line (Ksh 1,562 (18 USD) per person per month in rural areas, and Ksh 2,913 (33.7 USD) in urban areas per person per month) in each county in 2005/06 by the total population in each county. This indicator has a positive correlation with vulnerability to drought; the more poor, the higher the vulnerability.

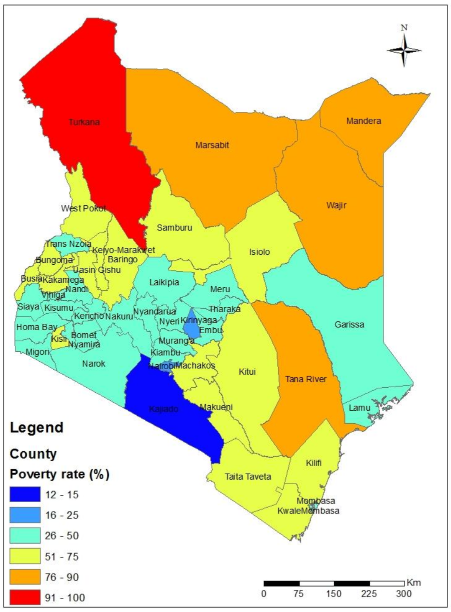

Figure 2.2 Population below poverty line per county

<u>Indicator: Literacy</u>

This indicator is based on the proportion of children between the ages of 10 – 14 years who could read and write. This information is based on the 2009 Kenya Population and Housing Census Report, 2010. The higher the percentage of literate population, the less vulnerable the population is to drought. This indicator is negatively correlated with vulnerability to drought.

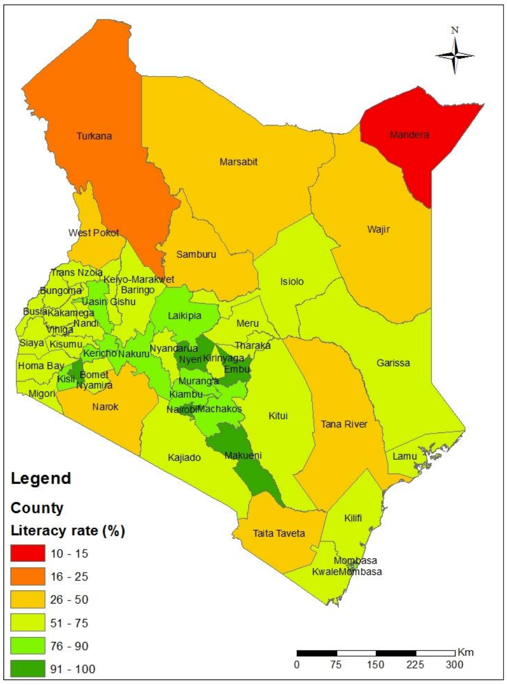

Figure 2.3 Literacy rate per county

Indicator: Life expectancy

The life expectancy is known for the country (WHO, 2011), but at the county level. Therefore we used as proxy data an estimation of the life expectancy per county based on the population of every county using the following simple calculation:

Life expectancy per county = average life expectancy of Kenya x population of the county / total population of Kenya.

This estimation relates the amount of population with the life expectancy. Another option would be to use the average life expectancy of Kenya for each county.

Life expectancy is negatively correlated with vulnerability, the higher the life expectancy per county, the less vulnerable. The older the population gets, the more chance is for knowledge transfer between generations. However, this indicator could also be positively correlated if we would consider that elder people are more vulnerable than younger people.

Indicator: Population without access to improved water

These data are generated from the 2009 Kenya Population and Housing Census Report, 2010, and present the proportion of Kenya households with access to improved water. Definitions for access to improved water are based on the Joint Monitoring Programme

(JMP) for Water Supply and Sanitation by the World Health Organization (WHO) and UNICEF. Accordingly, improved water sources include well/borehole, piped and rain-harvested water. This indicator is given per county and is positively correlated with drought vulnerability.

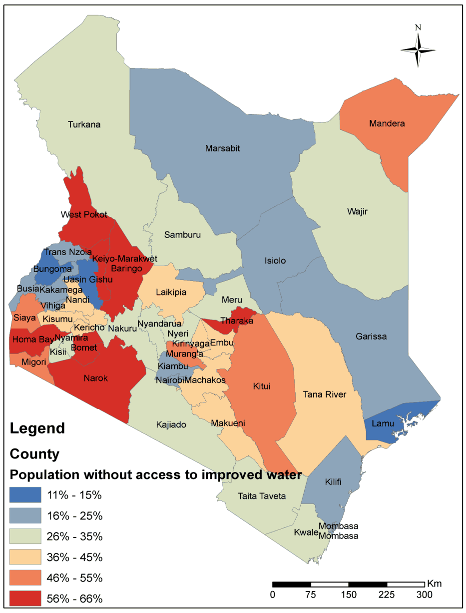

Figure 2.4 Percentage of population without access to improved water

<u>Indicator: Population without access to electricity</u>

This data, just like the data on population without access to improved water, was generated from the 2009 Kenya Population and Housing Census Report. This indicator is given per county and it is positively correlated with drought vulnerability.

<u>Indicator: Public participation</u>

Public participation is difficult to measure. Bollin and Hidajat (2006) proposed to use the percentage of voters that turned out in communal elections to indicate the level of public participation. We used the proportion of nationally registered voters per constituency (Kenya County Fact Sheets, 2011) as a proxy for public participation. Constituencies are the former territorial divisions in Kenya. Following promulgation of the existing Constitution in 2011, the number of constituencies had to increase from 210 to 290. Since the process of distributing the 290 constituencies among the 47 counties had not been finalized at the moment of creating the Kenyan Fact Sheets, the constituency distribution shown in the Fact Sheets is based on the 210 constituencies of 2011. Constituency populations are based on the 2009 Census, while county proportions of nationally registered voters is based on Independent Electoral and Boundaries Commission (IEBC) records as per the 2010 Constitutional Referendum. This indicator is negatively correlated with drought vulnerability; the more people participating in the elections, the lower the vulnerability to drought.

Indicator: Access to roads and infrastructure.

This indicator is considered important as it shows the facility of inhabitants to move across the country and therefore the facility to share knowledge and experiences. Moreover, a better access to roads implies more facilities to re(distribute) resources. This data is generated from District Development Plans (DDP), and reflects the proportion of Kenya's classified road network that is in good or fair maintenance condition. This indicator is negatively correlated with drought vulnerability.

Indicator: Access to information

This is considered an important indicator as more and better information and communication furthers the development of a society. This indicator can be calculated based on the percentage of radios, televisions or internet points per household. Unfortunately this information was not available at the time of this study and therefore it is not taken into account in the computation of the DVI. However, if data becomes available, we strongly recommend adding it in the DVI computation. The correlation with drought vulnerability is negative.

Indicator: Social networks

Social networks both virtual and physical are an indicator of the knowledge dissemination in the society. In our DVI for Kenya this indicator was indicated as being important by the experts. A possible way to measure it would be the number of local organizations dealing with drought. Unfortunately there was no data available at the time of this study and therefore it is not taken into account in the computation of the DVI. If data becomes available, we strongly recommend adding it in the DVI computation. The correlation of this indicator with drought vulnerability is negative.

2.1.2 Economic Capacity

Indicator: GDP per capita

The GDP per capita is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products, expressed in US dollars using purchasing power parity rates and divided by total population during the same period. The data comes from World Bank (2012). These data are available on the country scale. To obtain the GDP per county we multiplied the average GDP of Kenya per capita (1,507USD) by the county population. With this approach most populated counties get a higher GDP, which can be arguable. This indicator is negatively correlated with drought vulnerability.

Indicator: GDP by activity at constant prices

This indicator shows the economic diversification of the country. The economic diversification of income and resources of the country is frequently related to the economic stability of the country. Specifically, the more income and resources coming from non climate dependent sectors, the less vulnerable the country is to drought. In this case data on the GDP per activity for Kenya is available at country-scale. A way to calculate the index of diversification is using the following formula (Index from Rapkin, C.):

$$\boldsymbol{I = 1 - \frac{\sum(x_i)^2}{100^2}}$$

Where x_i is the percentage of total GDP in activity *i*. This index could have been calculated per county using the average GDP per capita per county (calculated based on the country average GDP and the population per county), and the country percentages of GDP per activity. However, this calculation assumes that the higher the GDP, the higher the economic diversification. As this is probably not linearly correlated, even though this is a key indicator, we decided to not include this indicator in the computation of the DVI.

Indicator: Agricultural GDP

The agricultural GDP gives an indication of how relevant agriculture is to Kenyan society. The available data is the national agricultural GDP (UNDP Human Developing Index), which has been divided into the counties depending on the area of cropland in each county. This indicator has a negative correlation with vulnerability to drought.

Indicator: Public expenditure

The public expenditure is calculated as the sum of the Constituency Development Fund (CDF), the Local Authority Transfer Fund (LATF), the Single Business Permit revenues (SBP), the Property tax revenues, and the Rural Electrification Programme Fund (REPF). This indicator is available per county and negatively correlated with drought vulnerability (Kenya County Fact Sheets, 2011).

The CDF are the actual allocations (2003/04 – 2008/09) and estimates (2009/10) for each of the 210 constituencies, which in turn are mapped to county boundaries. The data has been obtained from the CDF Board Website http://www.cdf.go.ke/ . Information on 2011 CDF spending or audited financial data was not available.

The LATF data has been obtained from LATF Annual Report and Review of Local Authority Financial Performance for the fiscal years 2007/08 and 2008/09. Taken together, LATF, SBP and Property taxes constitute the lion's share of resources available to Kenya's Local Authorities. While the property taxes and the SBP may be taken as a rough indicator of the core of future county own-source revenue streams, LATF can be used as an indicator of future needs of urban areas, and of the partial costs that could be faced by counties in delivering services.

For the REPF, the data come from the Rural Electrification Authority (REA) and relate to approved (not actual) spending on rural electrification programmes for the period 2003/04 – 2008/09.

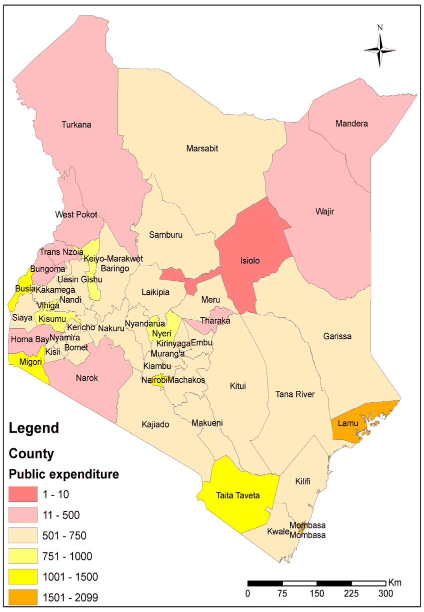

Figure 2.5 Public expenditure per county in Kshs (1Kshs is aprox 0.012USD).

<u>Indicator: Areas of cropland</u>

The areas of cropland in Kenya reflect the agricultural economic capacity of the country. The data was obtained from the World Resources Institute. The areas of cropland were then counted per county and used as indicator.

This indicator is double edged regarding drought vulnerability. On one hand, the more crop areas, the more income the population has and therefore if a dry period comes, the less is its vulnerability. On the other hand, more crop areas may indicate a strong dependence of the population on agriculture and therefore higher vulnerability to drought. However, the dependence of the population on agriculture is already included in the indicator economic diversification. Therefore, this indicator will be considered as negatively correlated with vulnerability to drought.

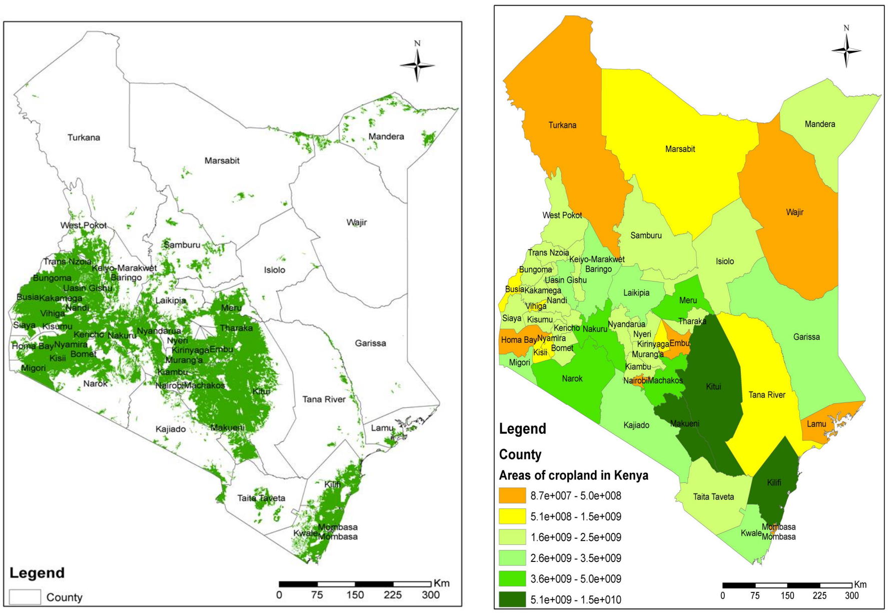

Figure 2.6 Areas of cropland per county. Left: original data from World Resources Institute. Right: processed data for this study in km^2 per county.

Indicator: Livestock population

The livestock population is counted as the number of cattle sheep, goats, camels, donkeys, pigs, indigenous chickens, commercial chickens and bee hives per county. This information comes from the Census Vol II Q 11: Livestock population by type and district – 2009 and is available in the Kenya Open Data website.

For this indicator the same double edge relation with drought vulnerability as with the areas of cropland applies. However, in the case of this indicator the experts tend to consider it as positively correlated with drought vulnerability because of cultural aspects. Even if the government offers the possibility to the farmer to sell his livestock in case a dry period is approaching, the farmer will probably not accept this offer and will stay with the livestock. When the dry period comes the livestock may, however, die due to the lack of water. The culture of the farmer does not contemplate selling livestock as a possibility to become less vulnerable to drought.

Indicator: Harvestable biomass

The harvestable biomass indicator is calculated as the annual growth of biomass outside the croplands and the theoretically harvestable biomass yield outside croplands in cubic meters per square kilometre. This data was aggregated per county and is considered as negatively correlated with drought vulnerability.

The data used to compute this indicator comes from the *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being*. To obtain the values in this Atlas, they grouped all areas classified as 'natural and semi-natural' in the Africover map (FAO 2000) into five broad vegetation classes (closed forest, woodland, bushland, wooded grassland, and grassland) based on their vegetation characteristics (38 different Africover codes). Each of the five broad vegetation classes was assigned the same average annual woody biomass growth rates as used in the Ministry of Energy (2002) study to estimate Kenya's biomass supply. Africover spatial units (polygons) with mixed vegetation classes (e.g., cropland interspersed with 'natural and semi-natural vegetation') were weighed by the respective area contribution. For the final map, total woody biomass growth (from standing natural biomass sources) for each Africover polygon was divided by its total polygon area to obtain growth of biomass in cubic meters per square kilometre per year. We counted the cubic meters per county per year and used this value as an indicator. The harvestable biomass is negatively correlated with the drought vulnerability because the more harvestable biomass, the more economic possibilities, the less vulnerable.

Indicator: Tourists visiting National Parks

The number of visitors per National Parks was disaggregated from National statistics and again aggregated per county according to the percentage of the area of a National Park in every county. The area of each National Park corresponds to Kenya protected areas. It is a subset of the Africa protected areas database from the World Conservation Monitoring Center's (WCMC), which manages a database on the worlds protected areas. Tourism is another source of income for Kenya and is considered to be negatively correlated with the vulnerability index.

2.1.3 Technological Efficiency

Indicator: Fertiliser consumption

The proportion of parcels using any type of fertiliser comes from the Kenya Integrated Household Budget Survey 2005-2006. This indicator is considered to give information of the agricultural technology. The more fertilizer consumption, the less agricultural technology is available and therefore the more vulnerable is the area to drought. Therefore it is correlated negatively with the drought vulnerability.

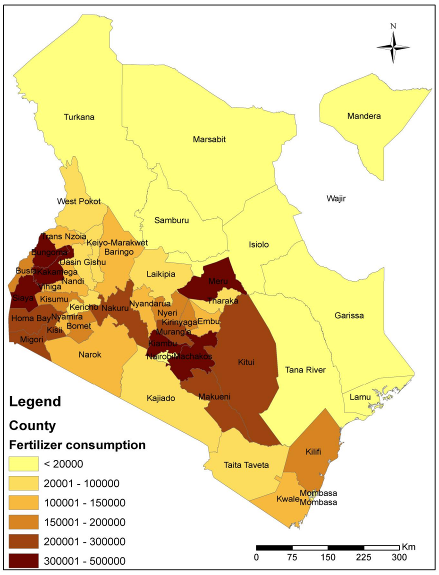

Figure 2.7 Fertiliser consumption per county as total number of parcels using fertilizer.

Indicator: Small scale irrigation

This indicator includes the number of small-scale irrigation and drainage points per county. It is considered an indicator of agricultural technology and therefore correlated negatively with drought vulnerability. However, the data available is relatively old (FAO Africover, 1995) and experts expect it to have changed quite a bit in the recent years. Unfortunately, more recent data was not available and we used this 1995 dataset in this study.

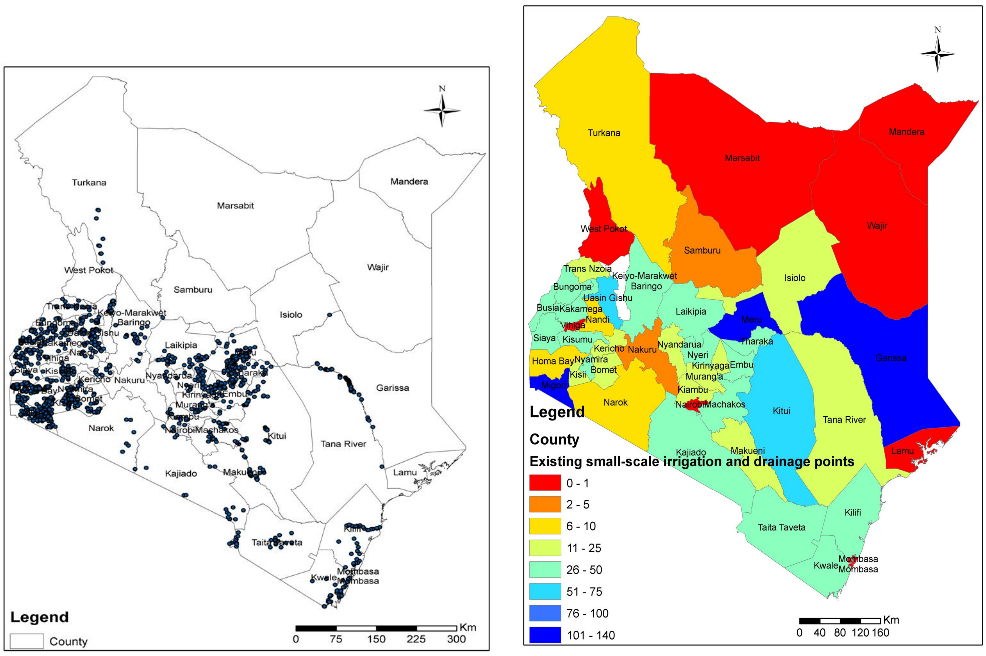

Figure 2.8 Number of small-scale irrigation and drainage systems. Left: original data from the World Resources Institute. Right: processed data for this study as number of drainage and small-scale points per county.

The data comes originally from The Ministry of Agriculture and Livestock Development (MoALD). 1995. District Profiles of Irrigation and Drainage in Kenya (All Districts). Nairobi: MoALD, Irrigation and Drainage Branch.

<u>Indicator: Use of ICT technologies</u>

This indicator is considered to be relevant as the use of ICT technologies shows a technological development of society. It should be considered as the use of ICT technologies in the main industries of Kenya. Unfortunately no data was available and therefore it is not included in the computation of the DVI.

<u>Indicator: Use of appropriated and indigenous technologies</u>

Appropriated technologies and indigenous technologies are considered to be crucial for the development of agriculture. The use of these technologies is therefore seen as an important indicator that is negatively correlated with drought vulnerability.
Again, unfortunately, no information was available and therefore it is not taken in the computation of the DVI.

2.1.4 Natural Capital

<u>Indicator: Average precipitation</u>

In the existing rain gauge network, most counties have at least one station with a long and reliable record of rainfall. For this study we used the mean annual rainfall for the period 1961-2011 (Department of Meteorology, University of Nairobi) which was calculated by taking the total rainfall from each of the 51 years, summing them up and dividing that sum by 51. This was done for each rain gauge.

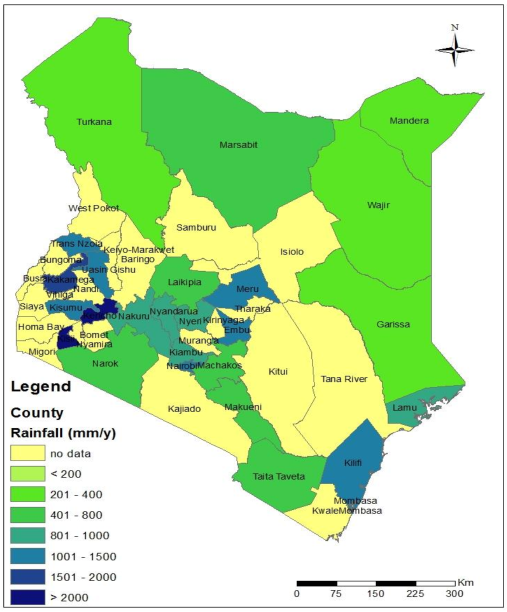

Figure 2.9 Average precipitation per county in mm/year as measured precipitation in meteorological stations.

Indicator: Water availability

Obtaining data on water availability is not trivial. According to the studies of FAO (Water Report 29, 2005), internal renewable surface water resources (including surface water and groundwater) can be estimated for the entire country. However, these resources are not equally distributed in the different counties and data about this is not available. Therefore this indicator, even though it is considered crucial for drought vulnerability, was not used for this study.

Indicator: Total water use

The total water withdrawn for agricultural, industrial and domestic purposes is computed for the entire country in millions of m3 per year. This is used as total water use indicator. The data comes from the studies of FAO (Water Report 29, 2005). We calculated the total water use per county dividing the total water use by the population per county and used it as proxy data. The water use is positively correlated with vulnerability to drought.

Indicator: Agriculture (irrigation and livestock) water use

Agriculture is one of the main economic activities in Kenya. Most of the agriculture is rain fed and only a small part is irrigated. Therefore the water used by agriculture is an indicator positively correlated with drought vulnerability. The data available comes from the FAO (Water Report 29, 2005) and is for the entire country. For this study we divided the total use of water for agriculture through the counties depending on the number of irrigations points per county. (See Figure 2.8: number of small scale and drainage systems).

Indicator: Average water consumption of livestock

The average water consumption of livestock is available per county and considered an important indicator positively correlated with drought vulnerability.

The data was generated by the Department of Resources Surveys and Remote Sensing (DRSRS) in cooperation with international agencies and is available in the World Resources Institute Website.

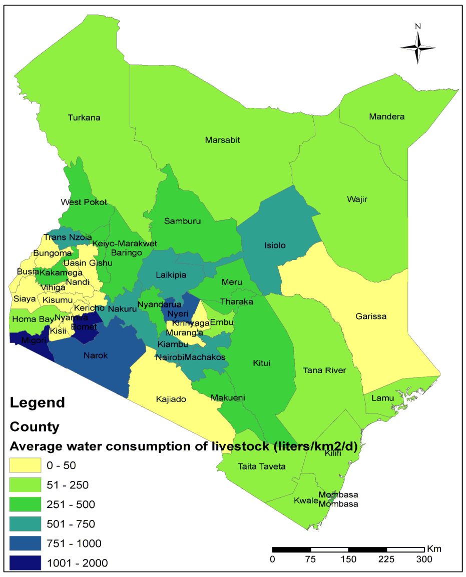

Figure 2.10 Average water consumption of livestock per county in $l/km^2/d$

<u>Indicator: Average water consumption of wildlife</u>

The average water consumption of wildlife is available per county. Although it is not a crucial indicator for drought vulnerability, Kenya is a touristic country mainly because of the existing wildlife, and therefore it is considered in this assessment. This indicator is positively correlated with drought vulnerability.

The data was generated by the Department of Resources Surveys and Remote Sensing (DRSRS) in cooperation with international agencies and is available in the World Resources Institute Website.

2.2 WEIGHTING THE INDICATORS

All the indicators mentioned in the previous section play a role in assessing drought vulnerability. However, not all are equally relevant, and not all equally relevant in all counties. For this reason we aimed to weight the indicators depending on their specific relevance.

During a workshop with the earlier mentioned experts, the weight given to each indicator was considered as a crucial exercise requiring an intensive study on itself. The experts pointed out that the weight of an indicator should be assigned per spatial unit where the DVI is calculated (in this case counties), and should depend not just on the relevance of an indicator, but also on the reliability or degree of confidence of the available data. Therefore giving one single weight value per indicator was not considered as feasible during the workshop, nor was it considered the right way to approach the weighting of indicators.

For this reason, and lacking the possibility to use a better approach, we weighted all the separate indicators equally and left the exercise of distributing weights per indicator for a future study. The weight given to each group of indicators (social capacity, economic capacity, technological efficiency and natural capital) depends on the number of indicators available within each group per county. In total we used 20 to 23 indicators per county. The reason for the range is the unavailability of data for some indicators for some counties.

In this way, the group of social capacity indicators included 8 or 9 indicators, accounting for a weight of 8 or 9 over 20, 21, 22 or 23 depending on the county. The group of economic capacity has 7 indicators and has a weight of 7/20-23. The group of technological efficiency has 2 indicators for all countries except for 1 and therefore a very low weight of 1-2/20-23. The weight of the group of natural capital ranges between 2-5/20-23.

The calculation of the weight of group of indicators has done as follows:

$$WI_{sc} = \frac{number\ of\ indicators\ in\ group\ Social\ Capacity\ per\ county}{all\ indicators\ in\ analysis\ per\ county}$$

$$WI_{ec} = \frac{number\ of\ indicators\ in\ group\ Economic\ Capacity\ per\ county}{all\ indicators\ in\ analysis\ per\ county}$$

$$WI_{te} = \frac{number\ of\ indicators\ in\ group\ Techn.\ Efficiency\ per\ county}{all\ indicators\ in\ analysis\ per\ county}$$

$$WI_{nc} = \frac{number\ of\ indicators\ in\ group\ Natural\ Capital\ per\ county}{all\ indicators\ in\ analysis\ per\ county}$$

2.3 CALCULATING THE DVI

For the calculation of the DVI the normalized values of the indicators and the weights were used. Every indicator was normalized using the following formulas:

$$N_i = \frac{x_i - x_{\max}}{x_{\max} - x_{\min}}$$

For indicators that were positively correlated with vulnerability, and

$$N_i = 1 - \frac{x_i - x_{\max}}{x_{\max} - x_{\min}}$$

for indicators that were negatively correlated with vulnerability.

Where:

N_i: normalized value for a certain indicator

X_i: value of that indicator in county *i*

X_{max}: maximum value of the indicator found in the group of counties

X_{min}: minimum value of the indicator found in the group of counties

The DVI was calculated using the sum of the normalized values available per group of indicators per county, and multiplying it by the weight of that group of indicators:

$$DVI_{per\ county} = f_{sc} * WI_{sc} + f_{ec} * WI_{ec} + f_{te} * WI_{te} + f_{nc} * WI_{nc}$$

Where:

f_{sc}: sum of the normalized values for the group of indicators of Social Capacity

f_{ec}: sum of the normalized values for the group of indicators of Economic Capacity

f_{te}: sum of the normalized values for the group of indicators of Technological Efficiency

f_{nc}: sum of the normalized values for the group of indicators of Natural Capital

The DVI resulted in values between 0 and 1. The closer the index is to 1, the more vulnerable is the county to drought.

3. RESULTS

Given the indicators described and weights assigned to each, the Drought Vulnerability Index found by country is shown in Figure 3.1.

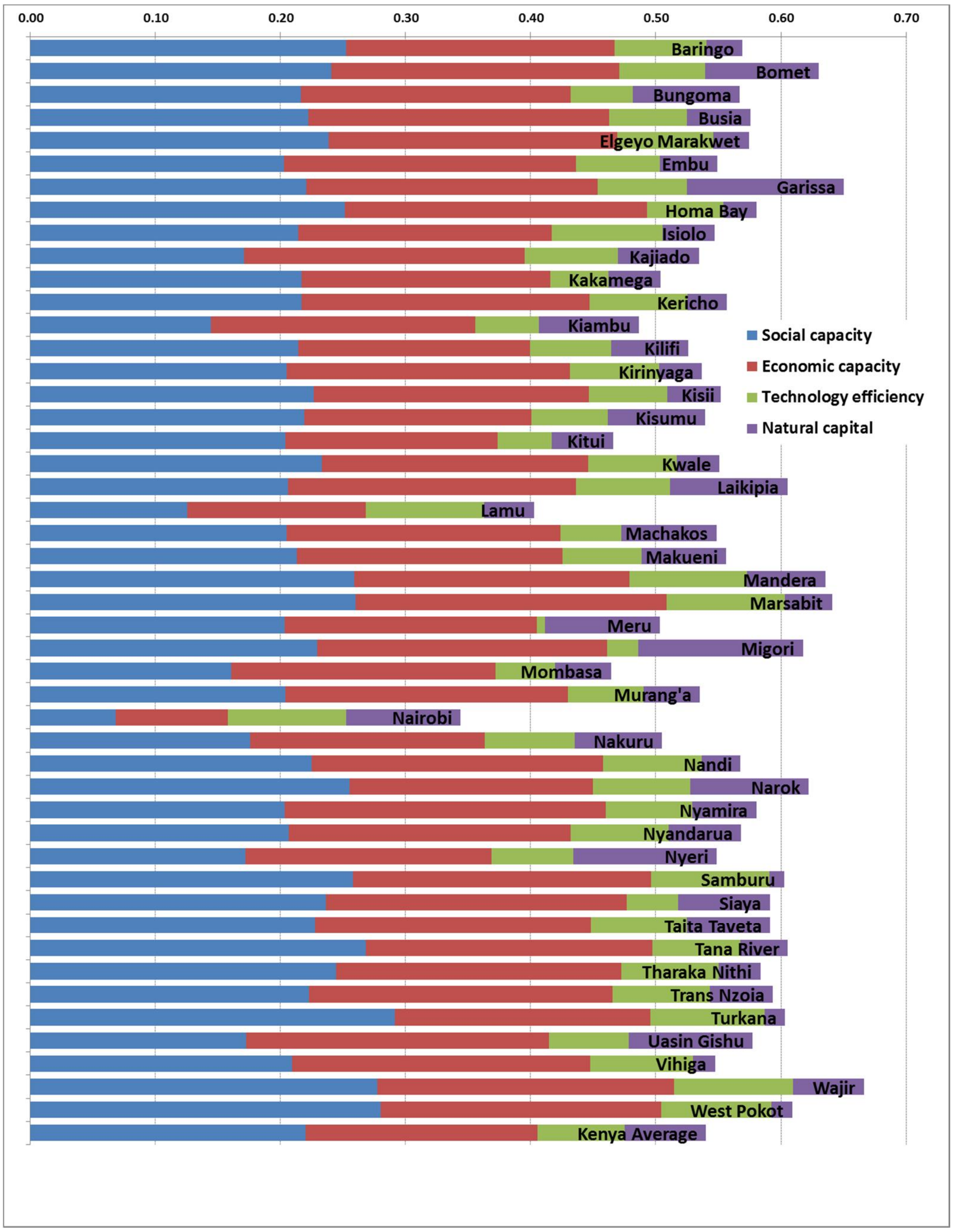

Figure 3.1 Vulnerability Index computed per county with weights.

Figure 3.1 shows that Nairobi is the least vulnerable county to drought mostly because of the low vulnerability of the social capacity indicators used for the computation. Nairobi has for example a low percentage of population without access to water and electricity, a high literacy rate, and a low percentage of population below the poverty line. In contrast, Wajir and Mandera are the most vulnerable counties mostly because of the low social and economic capacity. They both have a very low literacy rate, a high percentage of population without electricity, little access to roads and infrastructure, low public expenditure, and almost no tourism. A map of the data in Figure 3.1 is shown in the left side of Figure 3.2.

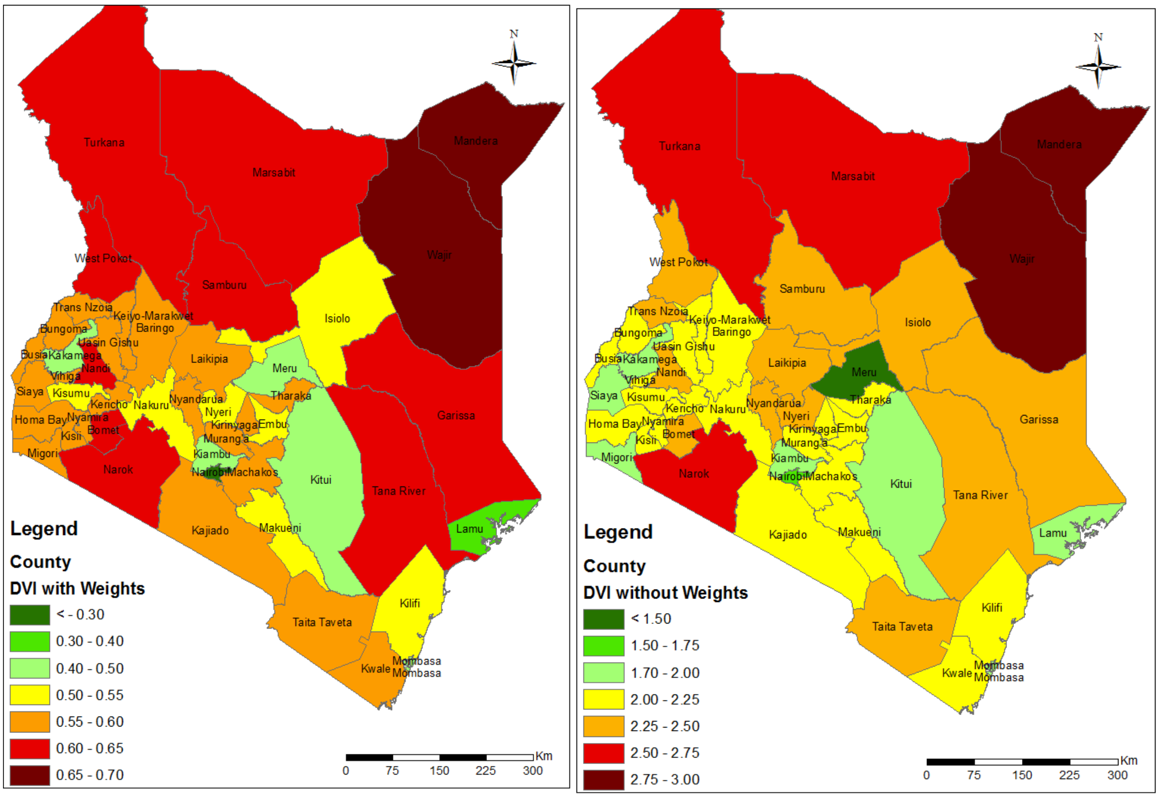

Figure 3.2 Drought Vulnerability Index Map of Kenya. Right: with weighted indicators. Left: without weighted indicators.

If all the indicators are taken with the same weight and we just sum their normalised values, we obtain the map shown on the right side of Figure 3.2. The clustering of the counties is obviously different in both maps because the method used to calculate the DVI is different as is the range of DVI values. However, there is a good match of the counties with higher, medium and lower vulnerability. Nairobi, Lamu, Meru, Kiambu and Kakamega are the least vulnerable, and Wajir, Mandera, Marsabit, Turkana and Narok the most . The reason to explore both methods lies in the fact that the weighting of the indicators could not been done within the scope of this study. The comparison of both methods shows that in this case, even when no weights are given to the indicators, the distinction between the most and the least vulnerable counties can be done.

4. CONCLUSIONS AND DISCUSSION

Kenya, due to its location, topography and climate, suffers from severe drought events with a return period of about 10 years. The vulnerability of the counties in Kenya to these drought events has been calculated using a Drought Vulnerability Index (DVI), based on a method developed within the DEWFORA project.

The method used to compute the Drought Vulnerability Index was discussed with a group of experts in different disciplines related to drought. The group recognised the method as appropriated to calculate drought vulnerability. They also acknowledged the chosen indicators and pointed out new ones considered to be important in Kenya or general?. Therefore we conclude that the list of indicators chosen to carry out the computation, if not complete, covers a thorough range of the possible indicators for drought vulnerability which are acknowledged by Kenyans as relevant.

The data used for the computation was mainly taken from public sources. However, some of the indicators considered important could not be established as the required data was not available, or was difficult to obtain. For some of the indicators proxy data were used or had to calculate based on assumptions. Another challenge was that the available data had different spatial resolution (national, division, subdivision, county), and was taken at different moments in time (1997, 2006, 2011, etc). Even though these deficiencies in the data can lead to limitations in its use, we considered the data relevant enough and therefore we used it for the DVI computation. In other cases, data was not available and we just mentioned the indicator as relevant but did not use it for the DVI computation as calculated in this study. A quantitative estimation of the impact of the missing indicators in the DVI is not workable within this study. However their impact is expected to be noticeable and we do recommend to including these indicators in further study.

The indicators were individually evaluated and discussed within the experts group. The group also established the correlation between the indicators and the drought vulnerability, which was not evident in all cases. In some cases, specific Kenyan cultural features determined the correlation of the indicator with drought vulnerability. For example, livestock population per county was seen as positively correlated with drought vulnerability because instead of indicating economic capacity, it increases the vulnerability as the dominant culture prevents farmers from selling livestock when a drought event is approaching.

Within the scope of this study we did not consider the correlation between indicators (for example rainfall and poverty index). Through for example principal component analysis the number of variables considered can be reduced, a step which was seen by the experts as something missing in the method. We recommend including this step in future development of this method for drought vulnerability assessment.

Establishing weights for each indicator was considered to be complex by the experts. Weights should be specified per indicator and per county, depending on the relevance of the indicator in that county and on the reliability of the available data. They recommended conducting a separate research to explicitly look at the weighting approach in order to select the right weights per indicator and per county. Within this study we used equal weights per indicator that were adjusted depending on the amount of available indicators per group (social capacity, economic capacity, technological efficiency and natural capital). The comparison of the results using weights with the results without using weights showed that the sensitivity of the method to the used weights is relatively limited. The results of the DVI computed with and without weighting the indicators were similar regarding the counties that are the most and the least vulnerable to drought.

Results show a heterogeneous vulnerability to drought within Kenya. DVI values range from 0.27 in Nairobi to 0.67 in Wajir, with a DVI of 0.56 being the average for the country. The distribution across the country of the index reflects the importance of choosing the right spatial resolution when applying the method. The results shown in this study should be taken as a preliminary indication as not all relevant indicators were used for the DVI due to missing data. We strongly recommend revising the DVI computation when more data is available.

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