RESPONDING TO CLIMATE CHANGE IN MOZAMBIQUE

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MINISTRY OF STATE ADMINISTRATION
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Instituto Nacional de
Gestão de Calamidades

CASE STUDY

Understanding the Socio-Economic Impacts of Climate Change and the Development of a Climate Proofing Strategy in the Limpopo river basin, Mozambique

Outcome 2 Report
Priority areas selected for climate proofing in the Limpopo river basin

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Climate Risk Management, Kulima,
Climatus, C4 EcoSolutions, CSIR
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1: Introduction

This project, as part of Phase 2 of the Instituto Nacional de Gestão de Calamidades (INGC) climate change programme, is undertaking an assessment of: i) the potential impacts of climate change in the Limpopo river basin in Mozambique (Gaza and Inhambane provinces); ii) the vulnerability of communities to climate change impacts within the basin; and iii) the adaptation options required to build community resilience and reduce disaster risk. Districts within the basin are often exposed to floods (which exacerbate vulnerability as settlements and livelihood activities are often situated on the fertile flood plains) and droughts (which contribute to water scarcity and crop failures).

The context of the project was provided in the Outcome 1 report, which presented i) the initial results of the downscaled climate projections for the basin and modelling the impacts on water resources and crop productivity under the median climate change scenario (Scenario 3); and ii) an analysis of the available socio-economic and social vulnerability data to understand the impacts to key economic sectors, and to gather the relevant data to develop a social vulnerability index.

This report represents the key deliverable of Outcome 2 of the project i.e. Identification on the priority areas for climate proofing in the Limpopo river basin. Identification of priority activities and initiatives will form part of the next phase of the project. The principle activities involved in gathering the information contained in this report have been:

- prioritising the sub-basins based on the flow and crop modelling results and presenting the data to highlight sub-basins where significant change (≥ 20% increase or decrease) is anticipated;
- prioritising the districts within the Limpopo river basin based on social vulnerability; and
- combining the flow and crop modelling data with the social vulnerability index to highlight priority sub-basins most vulnerable to the risks of future climate change.

2: Sub-basin prioritisation based on flow and crop modelling results

2.1 METHODS USED FOR PRIORITISATION

The flow and crop modelling results were presented in the first report as maps showing the relative increase or decrease in the modelled variables, as well as synthesis maps of the probability results. For this report, to allow an adequate evaluation of risks per sub-basin, the same results have been separated to represent increases and decreases in the modelled variables. Median values were used to prioritise the sub-basins, and probability values used to separate sub-basins with the same median value. The ten sub-basins most at risk have been highlighted per variable, representing 20% of the Mozambican sub-basins of the Limpopo river basin. The results are shown in Figures 3-14. A 20% change is seen as significant, and is represented by the darker colours (red for "drier" changes, blue for "wetter" changes). The different shades of red and blue in the figures represents different categories of change (Table 1). Figure 1 shows the sub-basins that were prioritised, and Figure 2 the sub-basin ID numbers. The rivers are not shown on the maps showing the priority basins for the sake of clarity.

Table 1: Colour scale used in maps showing the priority basins (Figures 3-14).

Drier		Wetter	
	0 % change		0 % change
	1 - 10 % change		1 - 10 % change
	11 - 20 % change		11 - 20 % change
	> 20 change		> 20 change

The results of the ten priority sub-basins for each variable are shown in Tables A1-A12 in annex A.

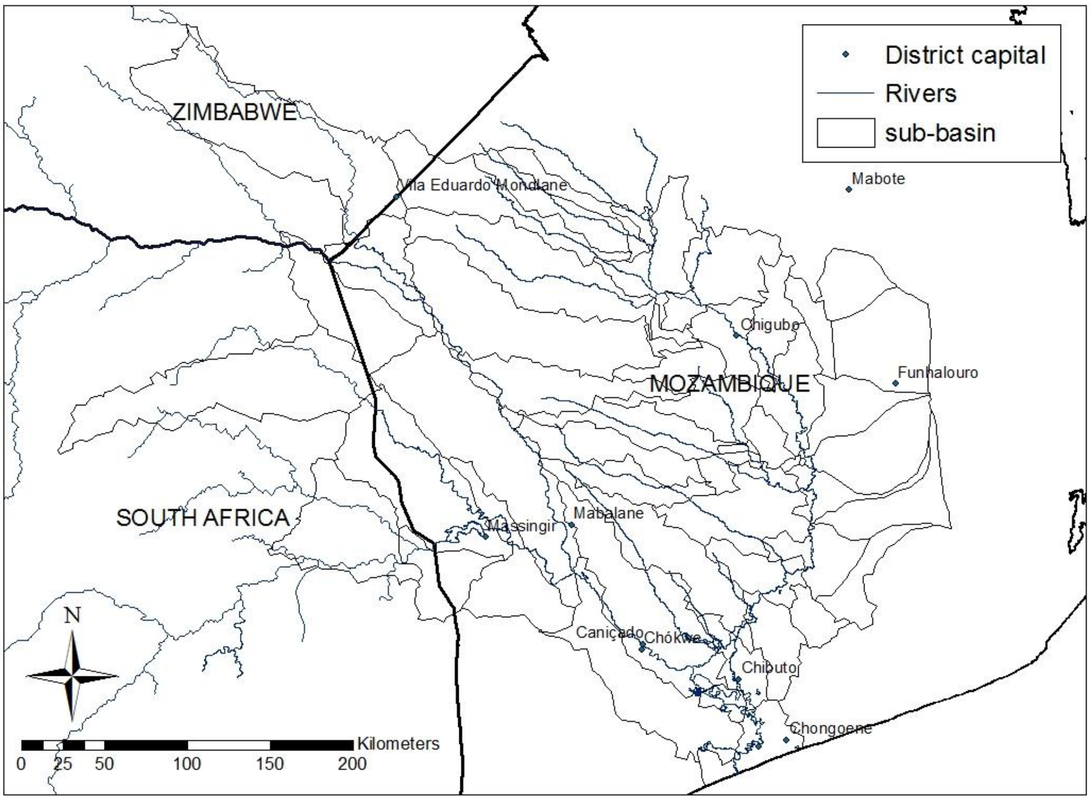


Figure 1: Mozambican sub-basins of the Limpopo river basin.

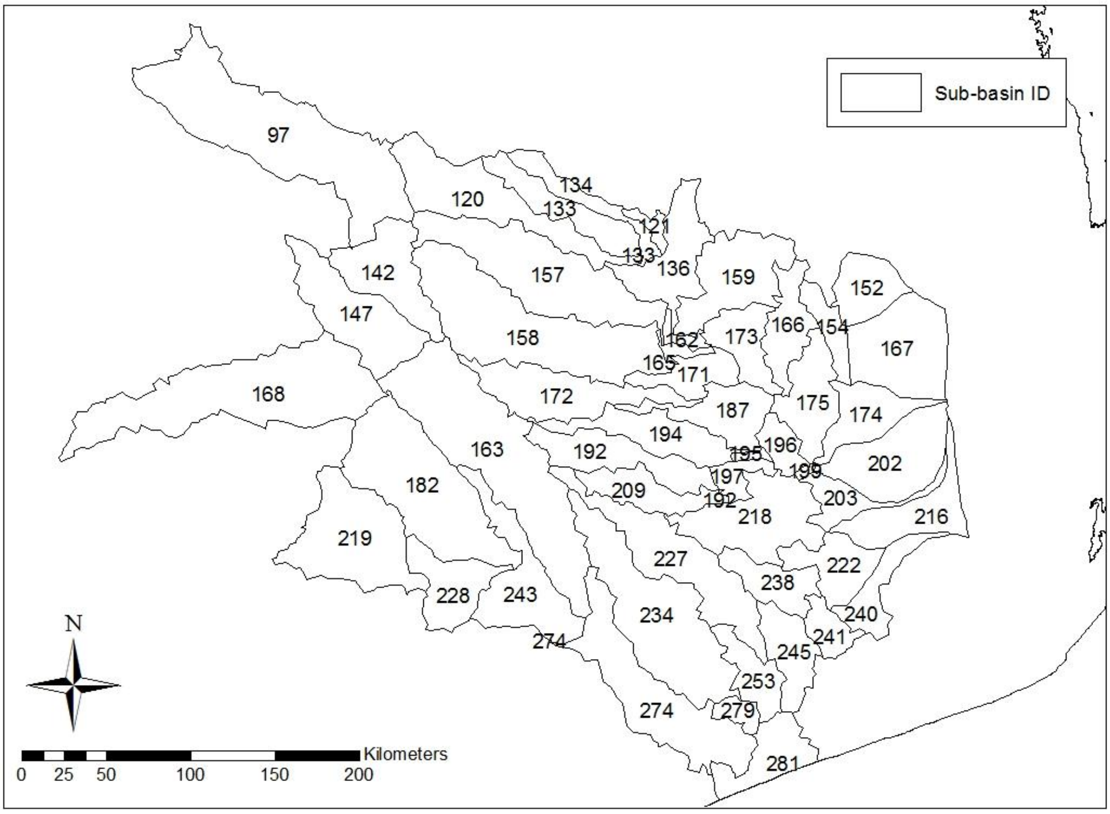
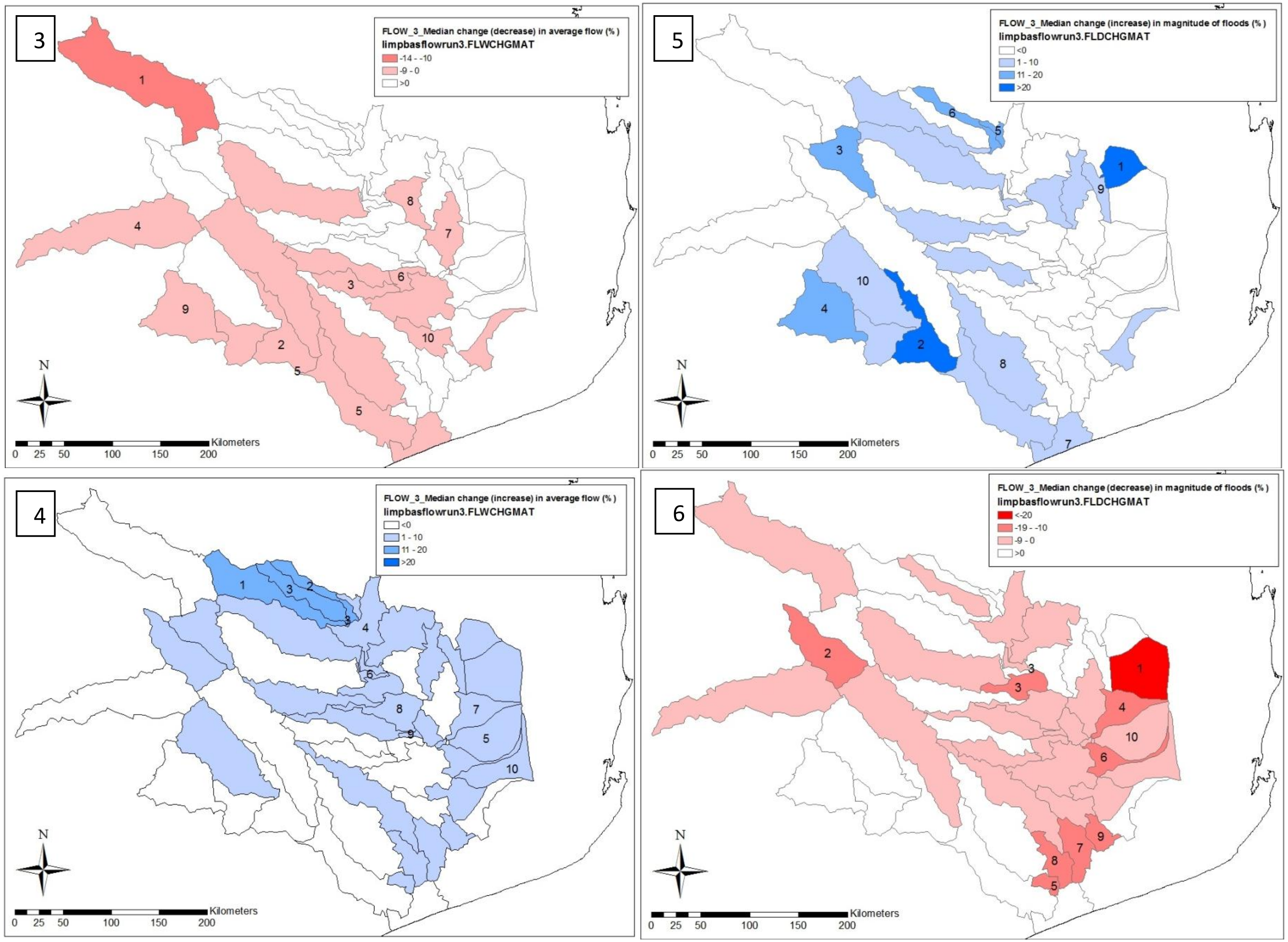


Figure 2: Sub-basin ID numbers.



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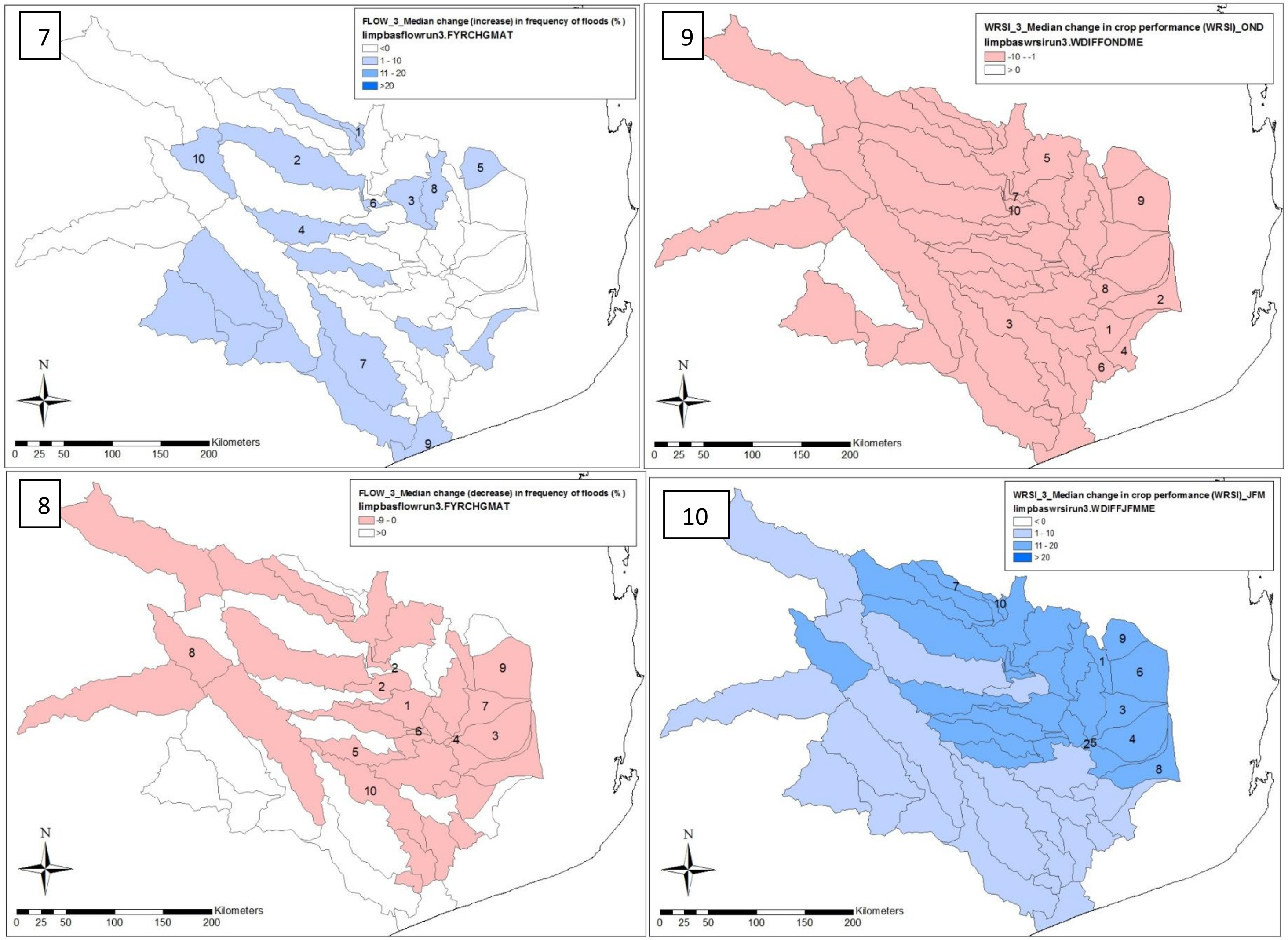
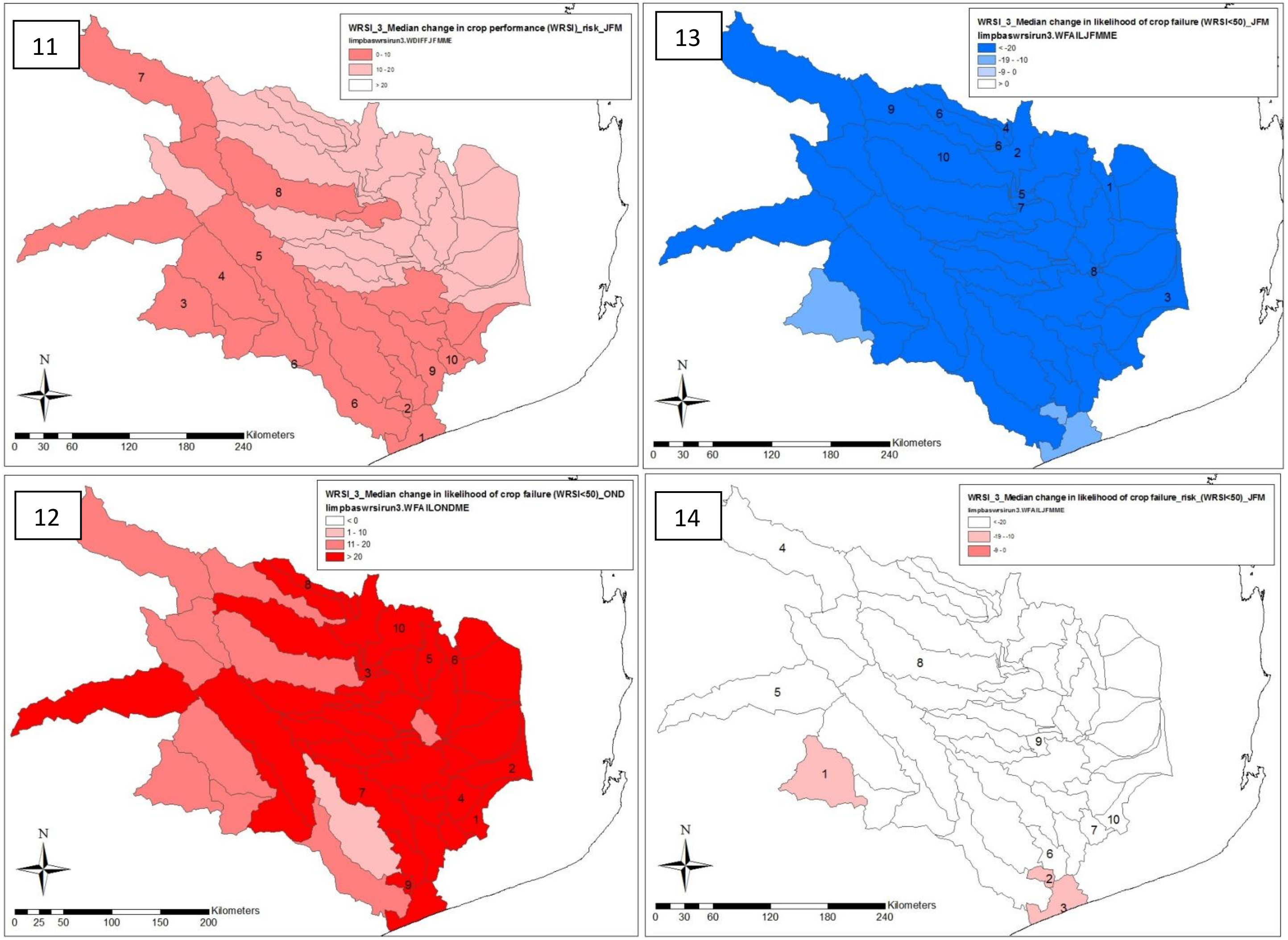


Figures 7-10: ***(7) Median % increase in frequency of flooding; (8) Median % decrease in frequency of flooding; (5) Median % change in crop performance for Oct-Nov-Dec; and (6) Median % change in crop performance for Jan-Feb-Mar (showing highest increases).***



Figures 11-14: (11) Median % change in crop performance for Jan-Feb-Mar (showing lowest increases); (12) Median % change in likelihood of crop failure for Oct-Nov-Dec; (13) Median % change in likelihood of crop failure for Jan-Feb-Mar (showing lowest likelihood); (14) Median % change in likelihood of crop failure for Jan-Feb-Mar (showing highest likelihood).

2.2 ANALYSIS OF RESULTS

2.2.1 Flow results

The highest **decrease in flow** (14% decrease, see Table A1 in Annex A) is predicted for the north-eastern most sub-basin, largely found within Zimbabwe. There were no changes of 20% predicted for any sub-basins. The other priority sub-basins are in the south-west of the basin, where decreases of 5-2% in flow are predicted (Figure 3). The highest **increases in flow** are predicted for the north of the basin where the results indicate increase of up to 17% (see Table A2 in Annex A). For the other priority sub-basins, in the north and east, increases of 8-10% are predicted (Figure 4). An **increase in magnitude of flooding** of 58% is predicted in sub-basin 152 in the north-east of the basin (Table A3 in Annex A). Other increases of >20% are predicted in two sub-basins in the west (Figure 5). The **decrease in the magnitude of flooding** represents an improvement in conditions, and is the converse of the increase. The highest decrease (21%, see Table A4 in Annex A)is predicted for the sub-basin adjacent to where the highest increase is predicted (Figure 6).The remaining highest decreases (8-14%) are scattered though the basin (with the exception of the south-west). The highest **increases in the frequency of flooding** are expected in the north of the basin (Figure 7). Results generally mirror that of the magnitude of flooding results. Highest predicted increases range from 2-9% (Table A5 in Annex A). Highest **decreases in the frequency of flooding**, as expected, mirror that of the decreases in magnitude of flooding (Figure 8, Table A6 in Annex A).

2.2.2 Crop performance and failure results

A **decrease in crop performance** is predicted in all sub-basins but one for Oct-Nov-Dec. Decreases, however, are low (all < 10%, Figure 9). Highest decreases are predicted for the east of the basin (Table A7 in Annex A). For the Jan-Feb-Mar planting season, however, an increase in crop performance is expected for all sub-basins (Figure 10). Highest increases (17.5%, Table A8 in Annex A) are expected in the east of the basin, where highest decreases are expected in the Oct-Nov-Dec planting season. Lowest increases in crop performance in Jan-Feb-Mar i.e. those sub-basins that stand to benefit the least from the improved conditions in Jan-Feb-Mar planting season (but still where increases are predicted) are in south-west and west of the basin (Figure 11). Lowest increases are in the 1.5-8% increase range (Table A9 in Annex A). An increase in the likelihood of crop failure is predicted for all sub-basins for the Oct-Nov-Dec planting season (Figure 12). Increases of 45-60% in the likelihood of crop failure are predicted for sub-basins in the centre and east of the basin (Table A10 in Annex A). Conversely, for the Jan-Feb-Mar planting season, a decrease in the likelihood of crop failure is predicted for all sub-basins (Figure 13). Highest decreases (58-115% decrease, Table A11 in Annex A) are predicted for the north-east of the basin. Lowest decreases in the likelihood of crop failure in Jan-Feb-Mar are predicted for the coastal sub-basins and one other in the south west (Figure 14). The results, however, still indicate a decrease in the likelihood of crop failure (Table A12 in Annex A), as opposed to the increase predicted for the Oct-Nov-Dec planting season.

3: Social vulnerability index at the district level for the Limpopo river basin

3.1 REVIEW OF VULNERABILITY INDICATORS AND INDICES

The nature of vulnerability is fundamental in determining whether hazard exposure will translate into adverse impacts. At the same time, social vulnerability as a potential state is difficult to assess due to the variety of determinants acting and interacting on different scales. It is therefore necessary to rely on indicators that best represent the complex underlying processes. These approaches have largely evolved over the last few decades in an attempt to build on existing case study based approaches developed primarily with regard to biophysical vulnerability. The expansion of conceptual and theoretical debates surrounding social vulnerability prompted recognition of the need to develop more systematic indicators to contribute to more holistic impact studies (Adger, 1999). With ongoing policy debates surrounding climate change and the need to prioritise adaptation interventions, indicators are still much discussed (Klein, 2009).

There have been several attempts at developing national level indicators and indices for social aspects of vulnerability, each varying in the nature of vulnerability addressed, the hazard involved, and the geographical region. There is a strong trend of each index building on and attempting to refine its predecessors by adding to the complexity. This can occur through a variety of means, for example increasing the number of variables considered, and/or using more sophisticated techniques of econometric and statistical modelling to transform and aggregate the indicators. Initial development of indices took place with reference to the small island developing state context (e.g. Briguglio, 1995; Crowards, 1999; Easter, 1999; Kaly et al, 1999a). An index of social vulnerability to climate change-induced changes in water availability has been created for Africa (Vincent, 2004). Others have taken more global approaches to assessing vulnerability and resilience, explicitly in regard to climate change (UNEP, 2001; Moss et al, 2001). Within the last year various explicit indices have been released, including the Global Adaptation Index[1], World Risk Index[2], and Climate Vulnerability Monitor[3].

3.2 METHODOLOGICAL DEBATES OVER INDEX CONSTRUCTION

The methodological debates on the use and construction of indicators have grown, commensurate with the range of indicators and indices (for a review, see Fuessel, 2009). One of the most fundamental distinctions is between an inductive (data-driven) or a deductive (theory-driven) approach (Niemeijer, 2002). In the former a large number of potential vulnerability indicators might be chosen in what has been labelled a vacuum cleaner approach (UNEP, 2001). Final selection might occur by means of expert judgement (Kaly and Pratt, 2000; Kaly et al, 1999a, 1999b), or principle components analysis to determine those that account for the largest proportion of vulnerability (e.g. Easter, 1999). However, the weakness in this is that a proxy variable for vulnerability must be chosen as the benchmark against which indicators are tested, somewhat paradoxically as the very need for vulnerability indicators is because there is no such

[1] http://gain.globalai.org/
[2] http://www.ehs.unu.edu/article/read/risk-index-maps-world-s-disaster-hot-spots-dw-world-de
[3] http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2010/

tangible element of vulnerability. In this case, therefore, the theory-driven approach is favoured, whereby use is made of existing theoretical insights into the nature and causes of vulnerability to select variables for inclusion, although in practice this necessarily occurs within the limits placed by data availability (Briguglio, 1995). This inevitably leads to subjectivity in the choice of indicators, but this can be addressed by ensuring all decisions are grounded in the existing literature and made fully transparent.

Although a number of indicators and indices have been devised for assessing social vulnerability to climate change, they cannot unproblematically be applied to the Limpopo basin. Indicators are context specific and typically cannot be transferred to different scales of analysis. Whilst the driving forces of social vulnerability might be similar, the appropriate indicator to capture that at a national level will likely be different from that at a sub-national level (Vincent, 2007; Eriksen and Kelly, 2007). A recent paper reviewed the use of indices in a variety of circumstances, concluding that they are most appropriate for identifying vulnerable populations at the sub-national level (Hinkel, 2011). Various indices have been created for assessing social vulnerability at community level (e.g. Vincent, 2007; Bell, 2011), including in Mozambique (Hahn et al, 2009). These community indices are based on household level data. For this index, data from household survey samples in villages has been aggregated to district level, in order to create a district level index of social vulnerability to climate change in the Limpopo Basin. An aggregate index is defined as one where the composition is not immediately apparent (Jollands and Patterson, 2003).

3.3 CHOICE OF INDICATORS AS DETERMINANTS OF VULNERABILITY

The aim of the social vulnerability index is to capture the operation and the dynamics of the processes that give rise to social vulnerability to climate change at the district level. There is a substantial literature that outlines the driving forces of vulnerability (e.g. Adger, 2006). Having made a theoretically informed decision on the determinants, simple and easily comprehensible indicators or proxy indicators need to be chosen, within the constraints of data availability. Making such choices is an inherently subjective process, and therefore it is important to outline the theoretical arguments for inclusion and assumptions relating to their functional relationship with vulnerability (i.e. whether it is a direct or inverse relationship) (see Table 2).

3.3.1 Financial Assets

Although poverty and vulnerability to climate change are by no means the same, there are a number of similar driving forces that give rise to both conditions. This is particularly the case in rural contexts in developing countries, where many people live below the poverty line and depend on natural resources for their livelihoods. Eking out an existence from day-to-day means that accumulating capital to acquire assets is a challenge. Not having such assets creates vulnerability to climate change, as households do not have access to finances that they can liquidise in case of a livelihood shock, such as might be created by a natural hazard (e.g. a drought or flood). Individuals with good access to resources arguably have a safety net in the case of environmental risk and exposure, allowing them to draw on other resources to maintain their livelihoods, and hence widening the range or intensity of hazards with which they can cope.

Various indicators could feasibly be chosen to represent financial assets. Options include the average balance in a bank account, or average value of farming implements. Given that livestock traditionally represent an accumulation of wealth in African societies (Crookes, 2003; Kalinda *et al.*, 2000; Reardon *et al.*, 1988; Swinton, 1988), the indicator chosen to capture financial assets is the average value of cattle per district. The higher the average value of cattle per district, the lower the vulnerability in the face of climate change, as there is a store of wealth that could be mobilised to maintain livelihoods. Of course there are problems with this hypothesis: in the case of a slow-onset hazard such as a drought, for example, the extent to which cattle are a resource depends on decisions their owners make with regard to selling them at the right time. If they wait too long, there is a risk of the market becoming flooded, and prices declining. Likewise in the case of droughts, in particular, cattle themselves can be an additional burden, as they require fodder crops to survive if there is insufficient pasture. In rapid-onset hazards such as floods, cattle may themselves be vulnerable to exposure in the same way that humans are.

3.3.2 Availability of liquid capital

In addition to financial capital stores, as measured here in value of cattle, another important determinant of vulnerability to climate change is the availability of liquid capital. As noted above, whilst cattle represent stocks of wealth, the ability to convert that stock into liquid capital is contingent upon the market at the time of the transaction. Availability of liquid capital, in the form of household cashflow, is also important in determining whether a household can respond to a climate hazard. In impoverished rural areas, such as the Limpopo basin of Mozambique, availability of cash is typically a scarce (Hanlon et al, 2010). Lack of availability of cash limits responses that can be made in the face of climate hazards, such as droughts and floods.

As with financial stocks, there are a variety of indicators that could potentially be used for availability of liquid capital. These could include cash available in a household over a set period, or relate to income. However, cash available is a function of the relationship between cash income and expenditure. For that reason, the indicator that is used here to represent availability of liquid capital is the ratio of income spent on food relative to total income. The higher the amount of income spent on food (for survival), the greater the level of vulnerability relative to a case where a smaller proportion of income is spent in food.

3.3.3 Household Dependency Ratio

The ability to build financial assets depends, to an extent, on the availability and quality of human capital. Human capital refers to the skills, knowledge, ability to form labour, and good health that allow people to pursue their livelihood strategies. Age is an important consideration as the elderly and young tend to be inherently more susceptible to environmental risk and hazard exposure (O'Brien and Mileti, 1992). The young and the elderly also place burdens on their families, requiring care and incurring expenses for education and health care. In general terms, populations with a low dependency ratio (high proportion of working age adults relative to children and adults) are likely to have the widest coping ranges and thus be least vulnerable in the face of hazard exposure.

Ideally the dependency ratio for a district should be ascertained as the proportion of children under the age of 18, and adults over the age of 60 or 65, relative to the working age population. Given the constraints of working with secondary data, it is not always possible to use the most appropriate categories. In the household economy survey, data was collected on the number of children under 18 in a household, and the number of working age adults, but not the elderly. In this case, therefore, the dependency ratio reflects only children to working age adults. However, this is not necessarily a problem, since the elderly in Mozambique are entitled to state social protection in the form of the *Programa de Subsidio de Alimentos* (Food Subsidy Programme). Despite its name, this is actually a cash-transfer programme similar to a pension, and it has the effect of turning the typical dependency ratio on its head, meaning that many elderly members of society now receive regular cash income, as opposed to relying on other family members.

3.3.4 Dependence on natural resources

By definition, the majority of people living in rural areas are engaged in natural resource-dependent livelihoods, such as farming, forestry and fishing. All these primary industries are intricately tied to the prevalent climatic conditions, and thus vulnerable to climate change. However, finding an appropriate proxy for natural resource dependence that is sufficiently sensitive to capture difference within rural areas is a challenge. For the social vulnerability index, the proxy that has been used is the average value of non-farm income accruing to each household within the district. Non-farm income sources in the Limpopo basin include construction, domestic work and petty enterprises. The hypothesis is that the higher the level of average income from non-farm sources, the lower the level of vulnerability to climate change. This is due to the non-reliance of these income sources on resource availability, and is simultaneously a measure of how diverse the livelihood portfolios. Impacts on farming, forestry and fishing, on the other hand, have already been projected under climate change in Mozambique (INGC, 2009).

3.3.5 Reliance on social support

As explained above, the vast majority of the Limpopo basin is rural and dependent on natural resources. Given that both climate variability and exposure to climate extremes are not new, livelihoods in the region have previously been subject to climate-related stressors. In particular, drought and flood conditions in the past have disrupted food security and necessitated external assistance for survival. If a district has had a high reliance on food support in the past, it is likely that it will be more vulnerable to climate change than a district which has not had such reliance. The indicator used here is the average receipt of grain (in kg) over the past year per district.

3.4 DATA SOURCE AND CONFIDENCE

Whilst the aim of the social vulnerability index is to be theory-driven, as suggested above this necessarily has to take place within the limits of the availability of robust and transparent comparable data. The most appropriate indicators were chosen from the available data set to capture the underlying theoretical determinants of vulnerability. All indicators used in the index came from Famine Early Warning System Network Livelihood Baseline Study (Fewsnet, 2011). Fewsnet regularly collects quantitative data pertaining to socio-economic characteristics through household surveys, and uses this information to devise livelihood zones. This baseline represents the first time that extensive data collection had been undertaken in the Limpopo basin. Questionnaires were undertaken with a sample of households in a selection of villages in each district. For the purposes of the social vulnerability index, district level data was formed through aggregating the mean value for each indicator from the relevant household questionnaires in each village.

Table 2: Summary of variables and indicators in the social vulnerability index.

Determinant of vulnerability	Indicator	What the indicator represents	Hypothesised functional relationship between indicator and vulnerability
Financial assets	Value of cattle	Average monetary value of cattle per district	The greater the value of cattle held within a district, the lower the level of vulnerability
Availability of liquid capital	Proportion of total income spent on food	Average ratio of expenditure on food relative to total income per district	The higher the proportion of total income spent on food, the greater the vulnerability.
Dependency ratio	Household dependency ratio	Average ratio of children under the age of 18 relative to working age adults within households in each district	The higher the dependency ratio, the greater the level of vulnerability.
Dependence on natural resources	Value of income from non-primary industry (farming, fishing, forestry) sources	Average income from non-primary industry (farming, fishing, forestry) sources per district	The greater the amount of non-farm income, the lower the level of vulnerability
Reliance on social support	Mass of grain relief	Average mass of grain relief received per year per district	The higher the mass of grain relief received per year, the greater the level of vulnerability.

3.5 METHOD OF AGGREGATION

Having considered the theoretical determinants of sub-national level social vulnerability and selected appropriate indicators to capture this, further methodological choices need to be made relating to the standardisation of indicators, and their means of combination into a single aggregate index.

3.5.1 Standardisation of indicators

Having selected indicators based on their theoretical role in determining social vulnerability, it is necessary to carry out some form of standardisation to ensure that they are comparable. There are several means by which this may occur. Most simply, standardisation fits variables to relative positions between 0 and 1. Some indices applied a normalisation procedure so that rather than refitting the actual range of values across the 0-1 scale, they are fitted to a normative scale of what is deemed high and what is deemed low. In the UNDP Human Development Index, for example, the GDP component index is calculated using goalposts of $40,000 as high (1 on the index) and $100 as low (0 on the index) (UNDP, 2002). However, normalisation adds an extra element of subjectivity, and may disguise any interactions between indicators. Whilst that may be useful in attempting to quantify actual vulnerability, as the purpose of this study is to assess relative levels the simple standardisation method will be used. All indicators are standardised so that the most vulnerable value in the range equates to 1, and the least vulnerable value in the range equates to 0.

3.5.2 Aggregation of indicators to form the index

Having standardised the indicators an appropriate means of creating the sub-indices needs to be selected. In a data-driven index this would require that the most appropriate indicators of vulnerability be selected from the shortlist. In the theoretically-driven approach, however, the importance of each of the variables in affecting sub-national level social vulnerability has already been determined. Whilst it is possible to weight indicators, in this index all indicators are deemed theoretically equal determinants of vulnerability. The process of aggregation thus involves simple averaging of the standardised indicator scores.

The overall equation summarising the model employed for the social vulnerability index for each district is thus:

$$SVI = \Sigma\ (I_i{*}0.2)(I_{ii}{*}0.2)(I_{iii}{*}0.2)(I_{iv}{*}0.2)(I_v{*}0.2)$$

where

I_i = financial assets
I_{ii} = availability of liquid capital
I_{iii} = dependency ratio
I_{iv} = dependence on natural resources
I_v = reliance on social support
0.2 = equal weighting based on there being 5 indicators

3.6 RESULTS AND DISCUSSION

This section summarises the results of the social vulnerability index (see Table 3 and Annex B). Although actual scores are presented it is worth reinforcing that these have been created by standardising indicators across the range of data for the districts in question, not across a normative range with theoretical high and low values. Therefore those districts at the top end of the range with "high" scores nearing one have the highest relative vulnerability (and are ranked accordingly). The districts at the bottom of the range with "low" scores nearer to 0 do not necessarily have low absolute social vulnerability, rather they are slightly better off compared to other districts in the Limpopo basin. In addition to overall scores, the indicators will be analysed in order to illustrate the variation in composition of driving forces that are reflected in the overall index scores.

In terms of overall social vulnerability, Massingir is the most vulnerable district, closely followed by Chicualacuala and Xai Xai (Figure 15). The districts with the relatively lower levels of social vulnerability are Mabalane, Chibuto and Chigubo. However, analysis of the component indicators adds further detail by showing the composition of the aggregate vulnerability. Massingir features as among the three most vulnerable districts in 3 component indicators: value of cattle, mass of grain received in the last year, and value of non-farm income (see Annex B). It also features as fourth most vulnerable in terms of spending on food as a proportion of total income. Analysing the composition of vulnerability within each district has important policy implications, as it highlights where interventions would be best placed to adapt to the changing climate.

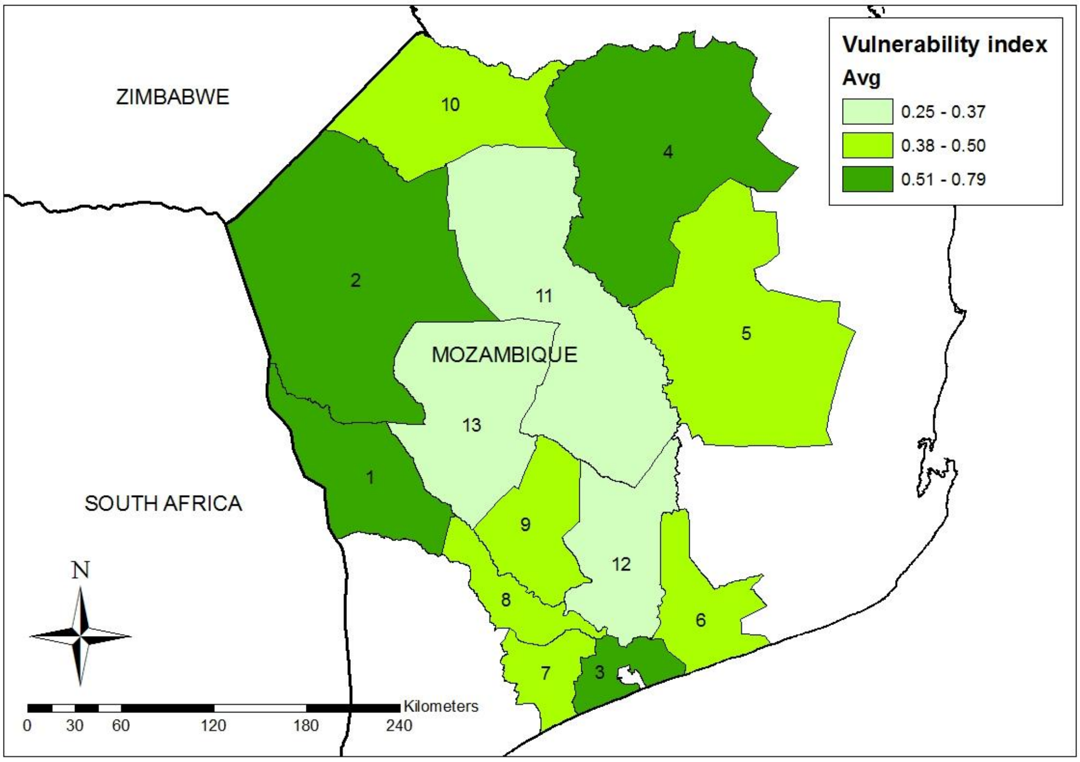


Figure 15: Vulnerability index of Mozambican districts in the Limpopo river basin.

Table 3: Vulnerability index results. The rank is shown in Figure 15.

Vulnerability Index			
District	*Average*	*Standard*	*Rank*
Massingir	0.79	1.00	1
Chicuacuala	0.67	0.79	2
Xai Xai	0.57	0.60	3
Mabote	0.55	0.55	4
Funhalouro	0.50	0.46	5
Manjakaze	0.48	0.43	6
Bilene	0.46	0.39	7
Chokwe	0.45	0.37	8
Guija	0.42	0.32	9
Massagena	0.40	0.27	10
Chigubo	0.37	0.22	11
Chibuto	0.32	0.14	12
Mabalane	0.25	0.00	13

3.7 EVALUATION OF RESULTS

As discussed, aggregate indices play an important role in simplifying multiple processes into a single figure. However, in doing so there is a danger of overlooking the subjectivity and using the figures uncritically. The best way of dealing with this is to develop a clear conceptual framework, identify the assumptions and sources of data, and maintain transparency in the choices of indicators, sub-indices, and aggregation functions (Jollands and Paterson, 2003; Hammond et al, 1995). Therefore an evaluation of the validity and reliability of the results depends as much on the critical analysis of methodological choices in the creation of the index as the figures and rankings themselves.

3.7.1 Data quality and availability

An index is only as good as the quality of the data sources it uses. In this index data has been taken from a Fewsnet survey. Fewsnet regularly undertakes household surveys of this style, and thus there is no reason to have undue suspicions about data quality.

3.7.2 Construct validity

Regardless of the quality of the data, the results are dependent upon how well the various indicators capture the identified determinants of vulnerability. The logic for choosing certain indicators to reflect the determinants of vulnerability has been outlined, but this is not an exact science – in many cases other indicators would have been equally appropriate to reflect the driving force of vulnerability. Likewise an evaluation of the index depends on scrutiny of how well assumptions hold about the functional relationship between the indicators and vulnerability.

3.7.3 Validation

The social vulnerability index essentially comprises predictive indicators of vulnerability based on existing theory. However it is extremely difficult to validate the effectiveness of the indicators in representing determinants of vulnerability as indeed the whole objective of the indicators is to capture intangible processes. A common method for assessing the validity of vulnerability and risk measures involves looking at correlations with past disasters data (Brooks and Adger; 2003; Pelling and Uitto, 2001; Crowards, 1999; Easter 1999). Whilst that may determine whether high levels of vulnerability contributed to hazard exposure translating into an impact, it gives less insight into the situations where low social vulnerability (high resilience) impeded the occurrence of a disaster. However, using historical occurrences of disasters and applying the model index to temporally-specific data might at least act as a means of validation for the structure of the index in explaining social vulnerability.

3.7.4 Limitations of capturing vulnerability in an index

In addition to the specifics relating to the social vulnerability index, a critical evaluation needs to take account of the limitations of indices in general when assessing vulnerability. Vulnerability is multi-dimensional in nature and a potential state that is time and scale specific. As a result, an index of social vulnerability is only a snapshot in time and may disguise ongoing evolutions of certain dimensions. Similarly it is impossible to represent the inter-relationships between different determinants or driving processes that interact in different ways according to the temporal and spatial scales of analysis (Wilbanks and Kates, 1999; Dow, 1992). The result here is an index of current social vulnerability, and holds should exposure to climate change (or a climate extreme) occur at the present. These conditions are unlikely to remain constant into the future when climate changes are projected to occur. However, although some indices have embraced the use of socio-economic scenarios (e.g. Moss et al, 2001), others suggest that current vulnerability is the best possible proxy (e.g. Adger and Kelly, 1999), and is appropriate for identifying the means of increasing resilience, coping ranges and adaptive capacity (Adger et al, 2003). Ideally this index should be annually updated with new data in order to capture temporal shifts.

Essentially the subjectivity involved in such an index will always be a problem, but the only solution is to use theoretical insights to ensure appropriate variables are selected, and then be transparent with the assumptions and subsequent methods of transformation from indicator to index. By doing this, the index is as durable as it can be in explaining relative levels of social vulnerability to climate change between districts in the Limpopo basin. However as with all indices it should be subject to a process of continual testing and refinement.

4: Combined sub-basin prioritisation

4.1 METHODS USED FOR PRIORITISATION

To combine the results of the social vulnerability index (district level) and those of the flow and crop modelling (sub-basin level), the social vulnerability averages were disaggregated to the sub-basin level in GIS. An average social vulnerability for each sub-basin was calculated, and the sub-basins prioritized. A combined value was then calculated as the product of the social priority and flow/crop priority levels. The results of this combined prioritisation are presented below in Figures 16-22. Sub-basins 97, 168 and 216 (west of the basin, see Figure 2) were excluded as these fall largely in Zimbabwe and Mozambique, and social vulnerability data was not representative of the whole basin. Only the risks were prioritised, not the opportunities (i.e. not increases in crop productivity).

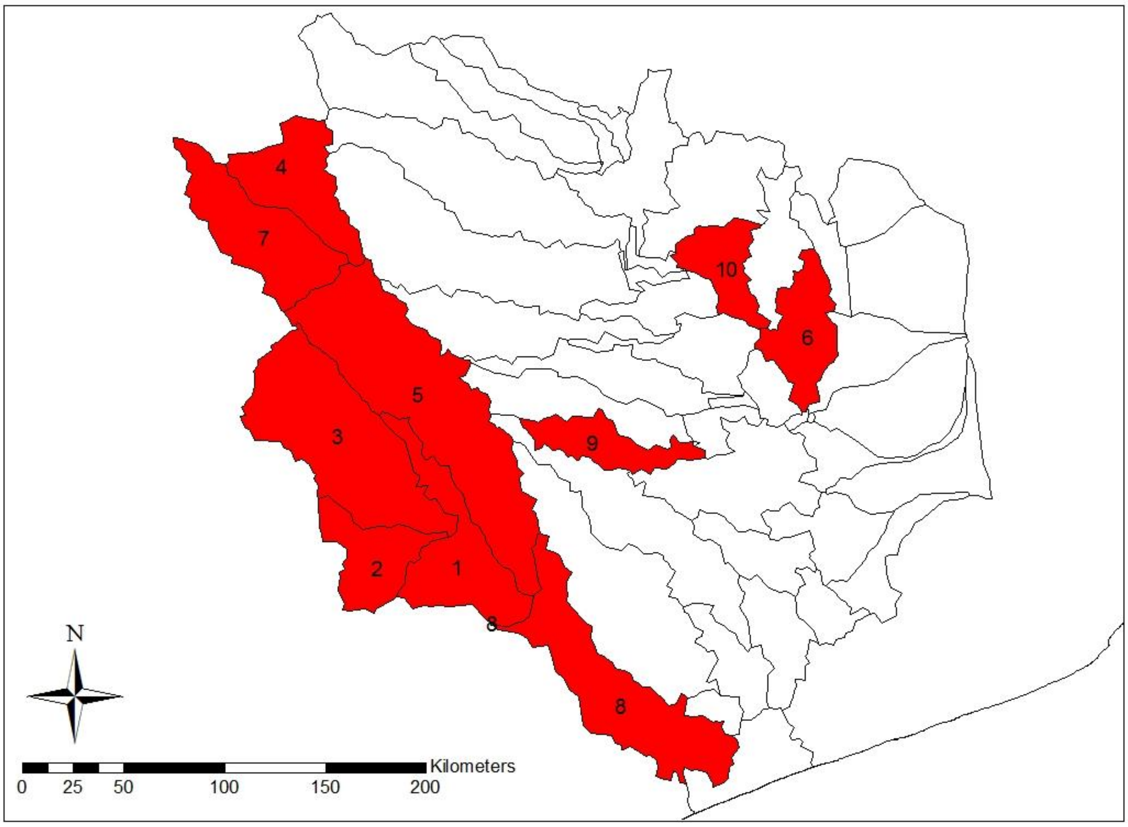


Figure 16: Priority sub-basins at risk due to a decrease in flow.

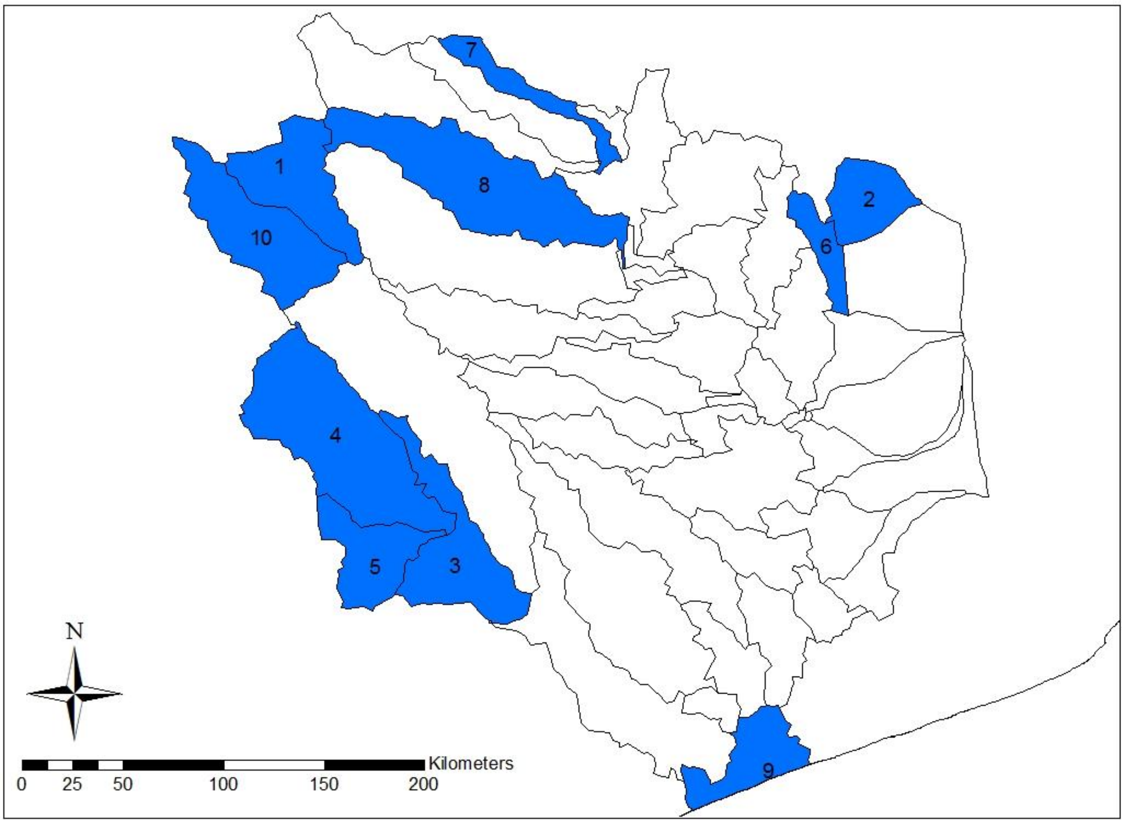


Figure 17: Priority sub-basins at risk due to an increase in magnitude of flooding.

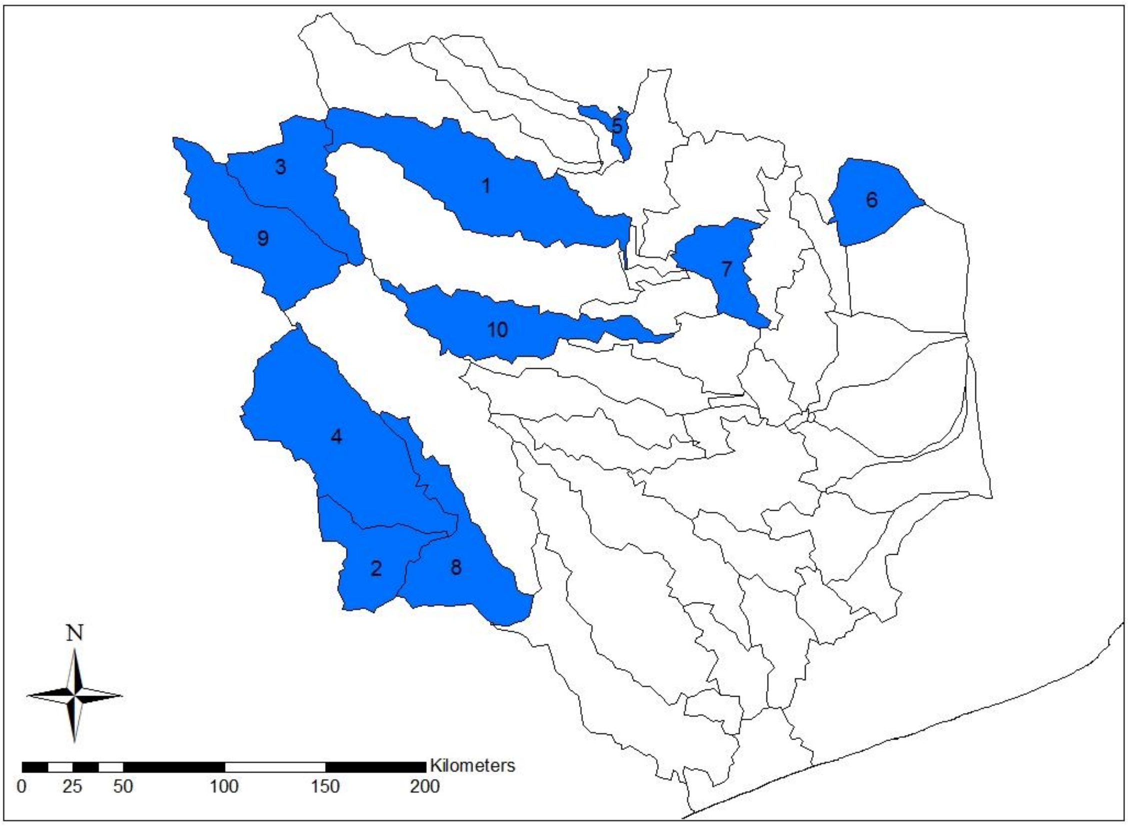


Figure 18: Priority sub-basins at risk due to an increase in frequency of flooding.

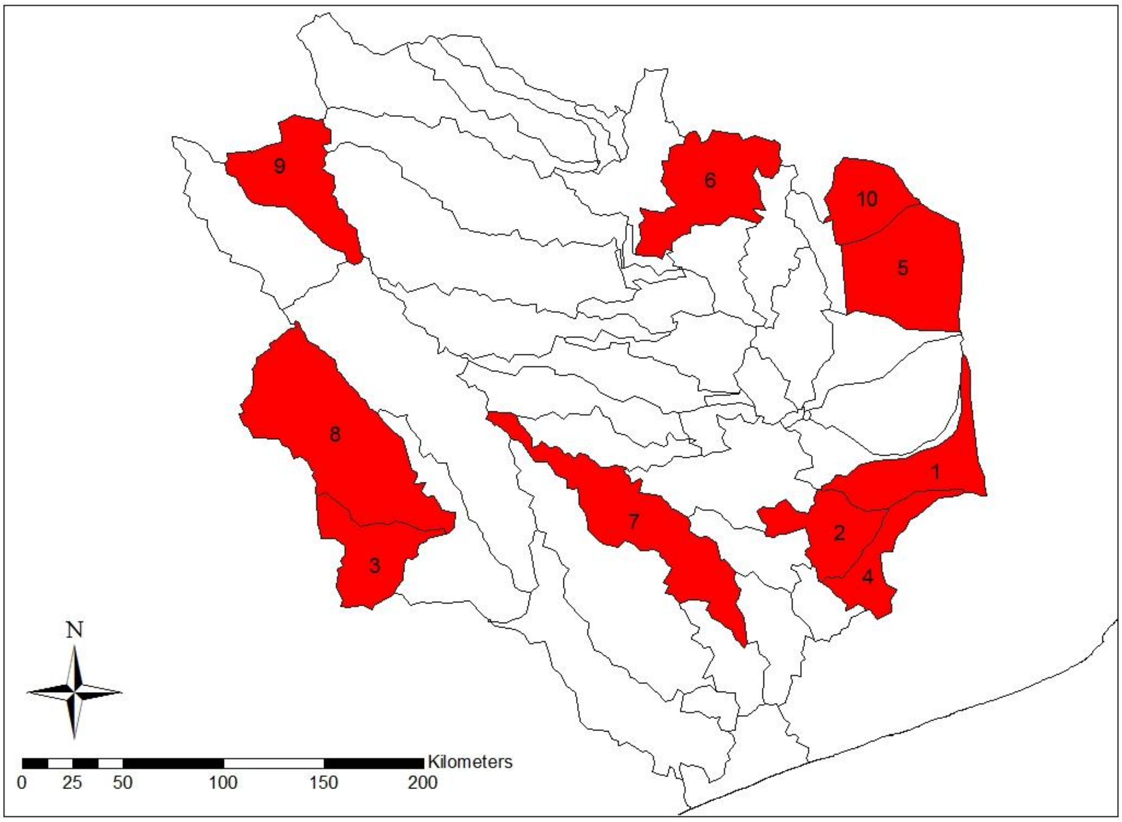


Figure 19: Priority sub-basins at risk due to a decrease in crop performance in Oct-Nov-Dec.

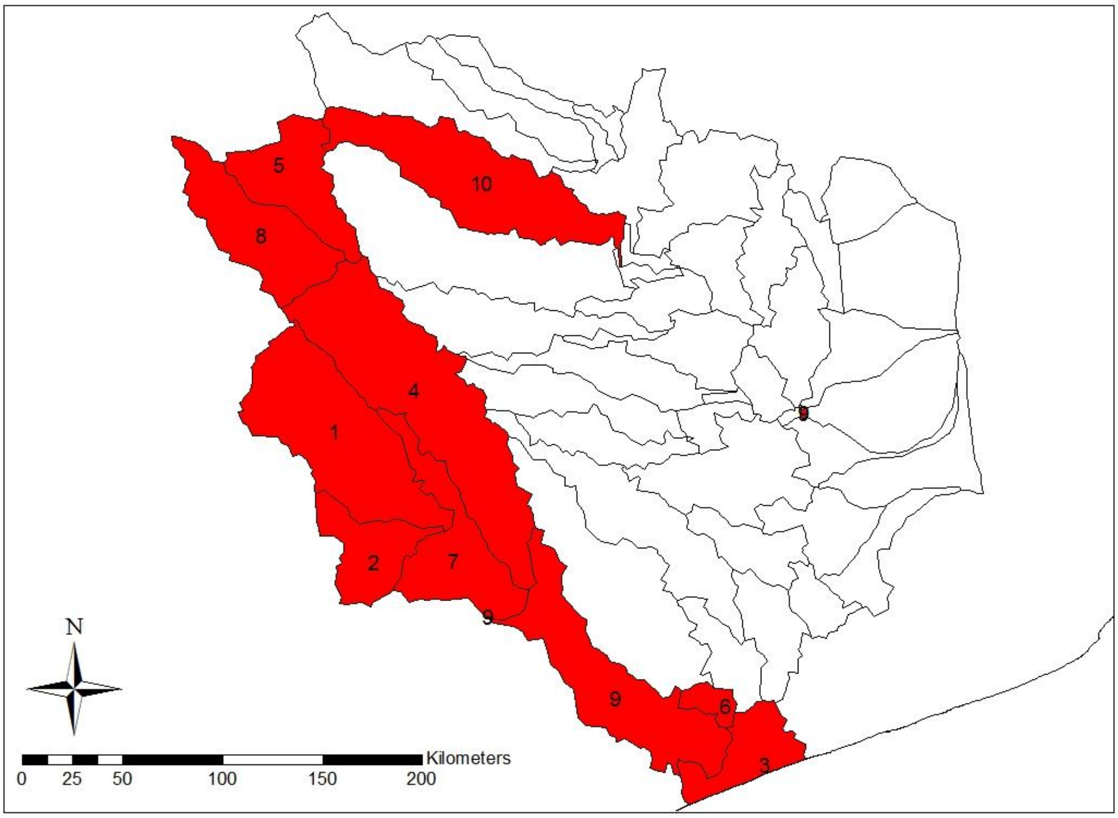


Figure 20: Sub-basins where the lowest increase in crop performance is predicted for Jan-Feb-Mar.

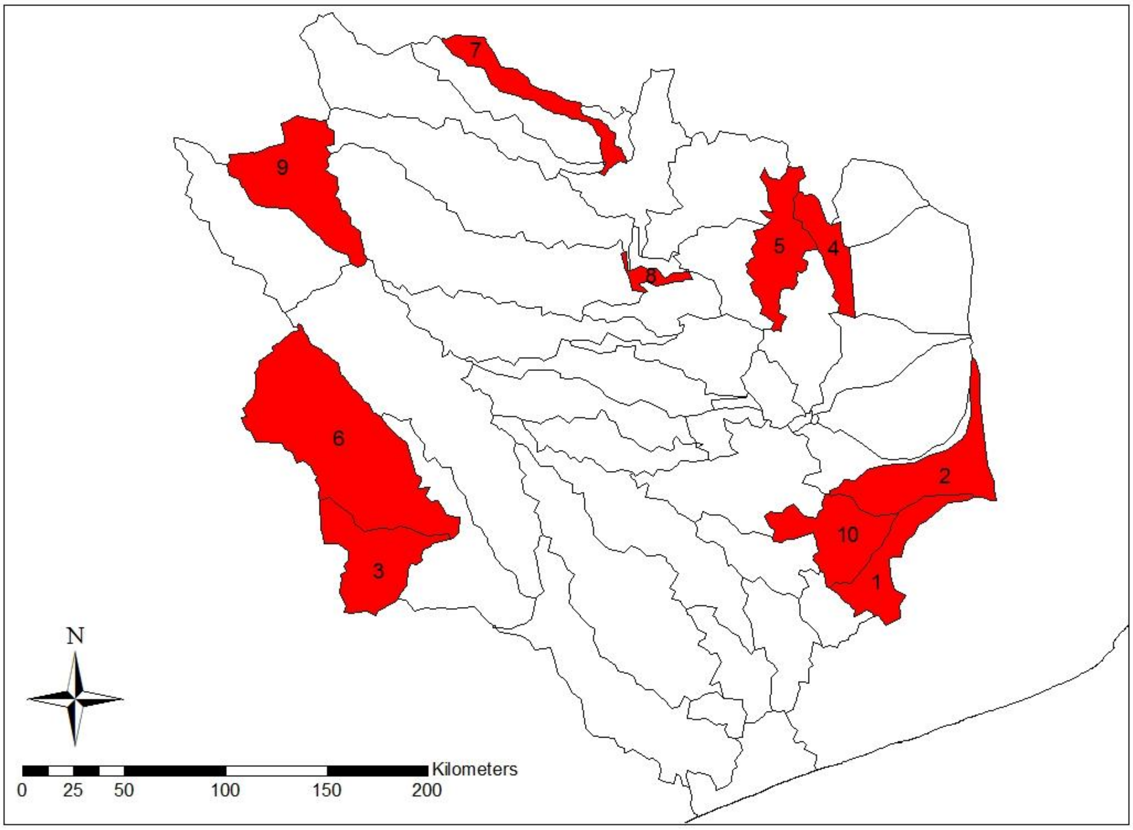


Figure 21: Sub-basins with the highest increase in probability of crop failure for Oct-Nov-Dec.

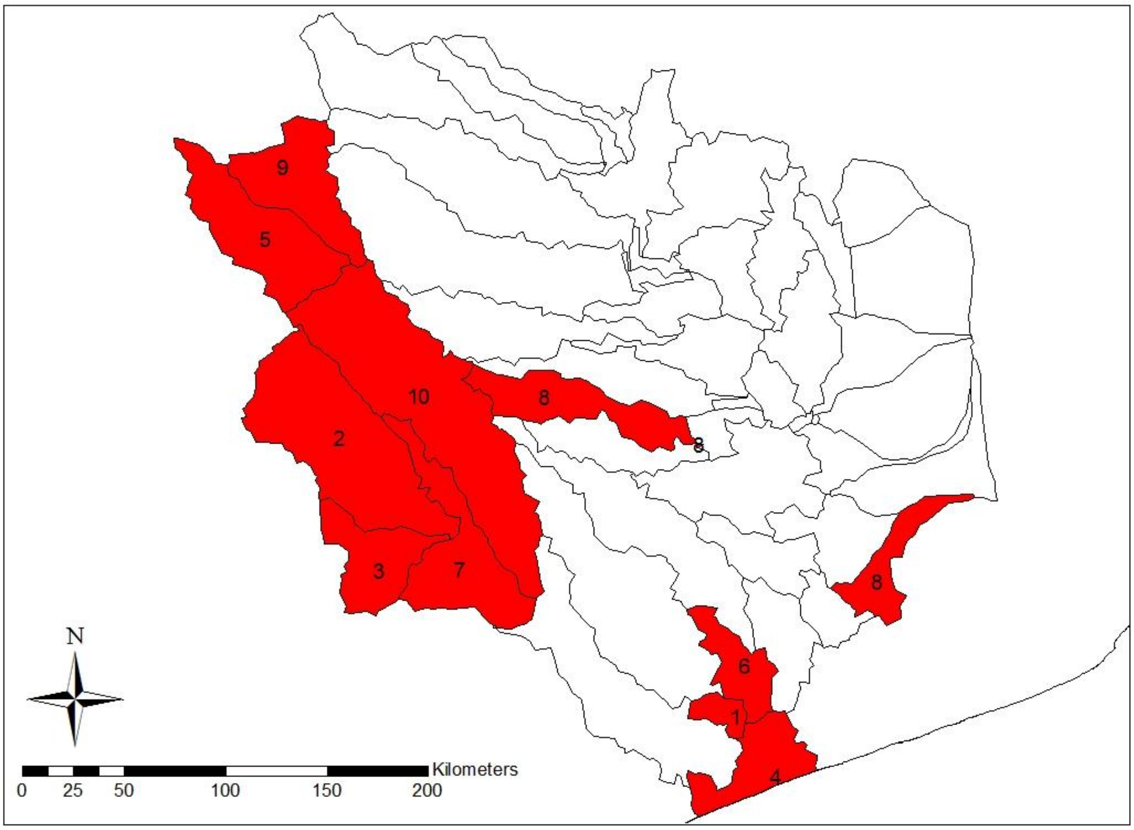


Figure 22: Sub-basins with the lowest decrease in the probability of crop failure for Jan-Feb-Mar.

4.2 PRIORITISATION OF SUB-BASINS FOR CLIMATE PROOFING

Priority basins where adaptation interventions should be focussed to counter the impacts of the predicted **decrease in flow** are located predominantly in the south-west of the basin (Figure 16). This is where the highest predicted relative decreases in flow are found, as well where the districts with the highest vulnerability index (Massingir, Chicualacuala and Xai Xai) are located. Priority sub-basins where the combinations of risk due to **magnitude of flooding** and social vulnerability are highest are scattered around the perimeter of the basin (Figure 17). Highest priorities are located in the west and south-west, as well as in the north-east where the highest increase in the change in magnitude of flooding is predicted (in the Funhalarouro District in Inhambane Province, 5th ranked in terms of social vulnerability). Priority sub-basins with regard to risk due to **frequency of flooding** generally mirror those most vulnerable due to magnitude of flooding, with a on the west and south-west of the basin (Figure 18).

The two priority sub-basins as a result of the risk of a combination of decreased **crop performance in the Oct-Nov-Dec** planting season and high social vulnerability are located in the south-east of the basin. These are the two sub-basins where highest decreases were predicted by the crop modelling, and are in the Funhalarouro and Manjakaze Districts. Other highest priority basins are scattered around the perimeter of the sub-basin, as well as in the central south (Figure 19). Least increases in **crop performance in the Jan-Feb-Mar** planting season (although still an increase relative to the current situation) are located in the south-west of the basin down to the coast (Figure 20), where social vulnerability is highest. The priority basins with regard **to probability in crop failure in the Oct-Nov-Dec** planting season generally mirror those of the decrease in crop performance in the planting season (Figure 21). Likewise, priority basins where the least probability of crop failure is predicted (i.e. most vulnerable in the Jan-Feb-Mar planting season) and social vulnerability is highest, are generally similar to those crop performance priority sub-basins in the same planting season (south-west, Figure 22).

The sub-basins where opportunities exist to capitalise on improved crop productivity and decreased likelihood of crop failure are outlined in Section 2.2.2.

5: Way forward

The next step in the project will be the outlining of key economic activities and initiatives most vulnerable to the impacts of the climate changes, based on the outcomes of the combined sub-basin prioritisation. This will involve a country mission and consultative process to facilitate agreement on by stakeholders on the prioritised areas, activities and initiatives. Specific actions to be taken for each of the priority activities and initiatives to ensure that the impacts of climate change on them are minimized will be identified and practical mainstreaming guidelines for integrating climate change considerations into the priority activities and initiatives will be developed. This will be developed into a climate proofing implementation strategy for the priority areas, with a proposed framework for a working mechanism. The Outcome 3 report will be available by mid-February 2012.

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Annex A: Flow and crop priority results

(Shown graphically in Figures 3-14)

Table A1: Median % decrease in flow.

Priority	Sub-basin ID	Median % change in flow	Probability of increase	Probability of no change	Probability of decrease
1	97	-14	20	30	50
2	243	-5	30	30	40
3	209	-5	20	50	30
4	168	-4	10	50	40
5	274	-4	20	40	40
6	197	-4	20	50	30
7	175	-3	30	30	40
8	173	-3	20	50	30
9	219	-2	20	50	30
10	238	-2	30	40	30

Table A2: Median % increase in flow.

Priority	Sub-basin ID	Median % change in flow	Probability of increase	Probability of no change	Probability of decrease
1	120	17	50	30	20
2	134	14	50	30	20
3	133	11	60	20	20
4	136	10	40	40	20
5	202	10	40	40	20
6	165	9	40	40	20
7	174	9	30	50	20
8	187	9	30	50	20
9	195	9	30	50	20
10	216	8	30	50	20

Table A3: Median % increase in magnitude of flooding

Priority	Sub-basin ID	Median % change in flood magnitude	Probability of increase	Probability of no change	Probability of decrease
1	152	58	50	40	10
2	243	28	50	20	30
3	142	20	50	40	10
4	219	17	50	20	30
5	121	17	50	20	30
6	134	12	50	30	20
7	281	10	40	30	30
8	234	8	30	60	10
9	154	7	30	60	10
10	182	6	40	20	40

Table A4: Median % decrease in magnitude of flooding.

Priority	Sub-basin ID	Median % change in flood magnitude	Probability of increase	Probability of no change	Probability of decrease
1	167	-21	20	30	50
2	147	-14	10	40	50
3	171	-13	20	30	50
4	174	-13	20	20	60
5	279	-12	30	20	50
6	203	-11	30	20	50
7	245	-11	30	20	50
8	253	-11	30	20	50
9	241	-10	30	30	40
10	202	-8	20	40	40

Table A5: Median % increase in frequency of flooding.

Priority	Sub-basin ID	Median % change in flood frequency	Probability of increase	Probability of no change	Probability of decrease
1	121	9	60	10	30
2	157	7	50	40	10
3	173	7	50	30	20
4	172	4	40	50	10
5	152	4	40	50	10
6	165	4	40	50	10
7	234	4	30	60	10
8	166	4	30	60	10
9	281	4	20	60	20
10	142	2	40	50	10

Table A6: Median % decrease in frequency of flooding.

Priority	Sub-basin ID	Median % change in flood frequency	Probability of increase	Probability of no change	Probability of decrease
1	187	-5	10	50	40
2	171	-5	20	40	40
3	202	-5	20	40	40
4	201	-5	10	60	30
5	209	-5	30	50	20
6	195	-5	10	70	20
7	174	-3	10	60	30
8	147	-3	10	60	30
9	167	-3	20	50	30
10	227	-3	30	40	30

Table A7: Median % change in crop performance for Oct-Nov-Dec.

Priority	Sub-basin ID	Median % change in crop performance Oct-Nov-Dec	Probability of increase	Probability of no change	Probability of decrease
1	222	-8	10	30	60
2	216	-7.5	10	20	70
3	227	-7	10	30	60
4	240	-7	10	30	60
5	159	-6	10	40	50
6	241	-5.5	10	40	50
7	162	-5.5	10	40	50
8	203	-5.5	10	40	50
9	167	-5.5	10	40	50
10	165	-5	10	50	40

Table A8: Median % change in crop performance for Jan-Feb-Mar (showing highest increases).

Priority	Sub-basin ID	Median % change in crop performance Jan-Feb-Mar	Probability of increase	Probability of no change	Probability of decrease
1	154	17.5	50	40	10
2	199	15.5	50	40	10
3	174	15.5	50	40	10
4	202	15.5	50	40	10
5	201	15	50	40	10
6	167	15	50	30	20
7	134	14	60	30	10
8	216	14	50	30	20
9	152	14	50	30	20
10	121	13.5	60	20	20

Table A9: Median % change in crop performance for Jan-Feb-Mar (showing lowest increases).

Priority	Sub-basin ID	Median % change in crop performance Jan-Feb-Mar	Probability of increase	Probability of no change	Probability of decrease
1	281	1.5	30	50	20
2	279	1.5	30	50	20
3	219	2.5	40	20	40
4	182	5	40	40	20
5	163	5.5	50	30	20
6	274	7.5	60	20	20
7	97	7.5	60	20	20
8	158	8	60	20	20
9	245	8	60	20	20
10	241	8	60	30	10

Table A10: Median % change in likelihood of crop failure for Oct-Nov-Dec.

Priority	Sub-basin ID	Median change likelihood of crop failure Oct-Nov-Dec	Probability of increase	Probability of no change	Probability of decrease
1	240	60	60	20	20
2	216	55	70	20	10
3	165	55	70	10	20
4	222	50	70	10	20
5	166	50	60	20	20
6	154	50	60	20	20
7	227	45	80	10	10
8	134	45	80	10	10
9	279	45	70	20	10
10	159	45	70	20	10

Table A11: Median % change in likelihood of crop failure for Jan-Feb-Mar (showing lowest likelihood).

Priority	Sub-basin ID	Median change likelihood of crop failure Jan-Feb-Mar	Probability of increase	Probability of no change	Probability of decrease
1	154	-115	20	30	50
2	136	-110	20	10	70
3	216	-105	20	20	60
4	121	-95	20	20	60
5	162	-95	20	20	60
6	133	-90	20	10	70
7	165	-90	20	20	60
8	199	-90	20	30	50
9	120	-85	20	10	70
10	157	-85	20	20	60

Table A12: Median % change in likelihood of crop failure for Jan-Feb-Mar (showing highest likelihood).

Priority	Sub-basin ID	Median change likelihood of crop failure Jan-Feb-Mar	Probability of increase	Probability of no change	Probability of decrease
1	219	-7.5	20	40	40
2	279	-15	20	30	50
3	281	-15	40	10	50
4	97	-22.5	20	60	20
5	168	-22.5	20	60	20
6	253	-30	20	10	70
7	241	-35	20	20	60
8	158	-40	20	10	70
9	197	-45	20	20	60
10	240	-45	20	20	60

Annex B: Social vulnerability

The results below were used to calculate the vulnerability index presented in Table 2 and Figure 15.

Cattle			
District	**Average**	**Standard**	**Rank**
Mabote	5.17	1.00	1
Xai Xai	6.05	0.95	2
Massingir	6.73	0.92	3
Chicuacuala	10.47	0.73	4
Guija	14.76	0.51	5
Funhalouro	14.79	0.51	6
Chigubo	15.67	0.47	7
Bilene	16.96	0.40	8
Chibuto	17.00	0.40	9
Mabalane	17.30	0.38	10
Manjakaze	21.39	0.17	11
Chokwe	22.77	0.10	12
Massagena	24.79	0.00	13

Spending			
District	**Average**	**Standard**	**Rank**
Chokwe	0.48	1.00	1
Chigubo	0.39	0.74	2
Bilene	0.38	0.73	3
Massingir	0.35	0.66	4
Mabote	0.30	0.50	5
Chicuacuala	0.28	0.46	6
Massagena	0.24	0.34	7
Manjakaze	0.22	0.28	8
Xai Xai	0.22	0.28	9
Guija	0.22	0.28	10
Funhalouro	0.15	0.09	11
Chibuto	0.13	0.03	12
Mabalane	0.12	0.00	13

Grain			
District	Average	Standard	Rank
Bilene	54.06	1.00	1
Massingir	52.08	0.96	2
Chokwe	37.50	0.69	3
Funhalouro	31.67	0.59	4
Xai Xai	31.25	0.58	5
Manjakaze	29.13	0.54	6
Chicuacuala	23.00	0.43	7
Chibuto	20.00	0.37	8
Chigubo	6.25	0.12	9
Mabote	-	0.00	10
Guija	-	0.00	11
Mabalane	-	0.00	12
Massagena	-	0.00	13

Non-Farm Income			
District	Average	Standard	Rank
Massagena	5 851.34	1.00	1
Massingir	6 053.15	0.98	2
Manjakaze	6 399.94	0.95	3
Xai Xai	6 782.28	0.91	4
Guija	7 358.50	0.86	5
Chicuacuala	7 901.03	0.81	6
Mabote	8 697.27	0.74	7
Funhalouro	13 509.57	0.29	8
Chigubo	14 347.91	0.21	9
Bilene	14 874.74	0.16	10
Mabalane	15 048.31	0.14	11
Chokwe	15 563.19	0.10	12
Chibuto	16 603.40	0.00	13

Dependency Ratio			
District	Average	Standard	Rank
Funhalouro	2.05	1.00	1
Chicuacuala	2.01	0.95	2
Chibuto	1.89	0.82	3
Mabalane	1.79	0.72	4
Massagena	1.72	0.64	5
Mabote	1.59	0.50	6
Manjakaze	1.56	0.48	7
Guija	1.54	0.45	8
Massingir	1.51	0.42	9
Chokwe	1.44	0.34	10
Chigubo	1.41	0.31	11
Xai Xai	1.24	0.13	12
Bilene	1.12	0.00	13