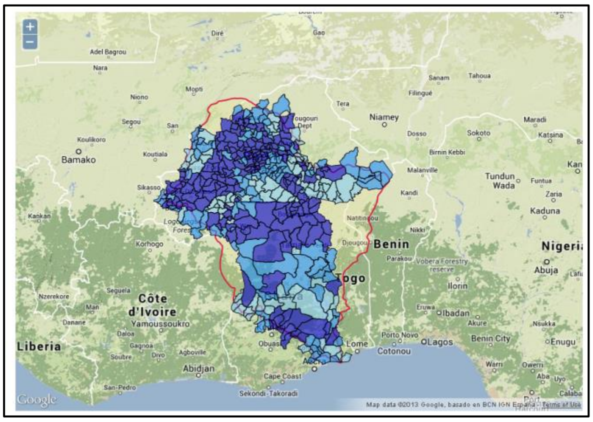
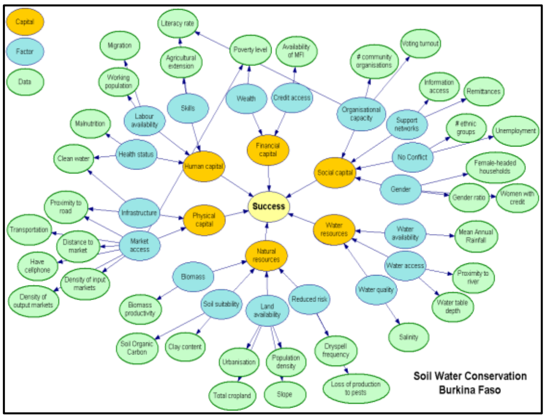
Technical Information Brief: TAGMI Bayes Network Model





AUTHORS

KEMP-BENEDICT Eric (SEI)

MORRIS Joanne (SEI)

FENCL Amanda (SEI)

WANG Guozhong (SEI)

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INTRODUCTION

Project Aim: To produce a framework and web-based “decision support”, (or targeting and scaling out tool) that will assist in identifying sites where the introduction of AWM interventions for smallholder farming systems are likely to be successful.

The key elements of the tool are: i) a Bayesian network model; ii) a database of district-level contextual data; iii) a program written to run the Bayes model simultaneously for all districts in a country; and iv) the web interface that displays the results as a map. (Figure 1)

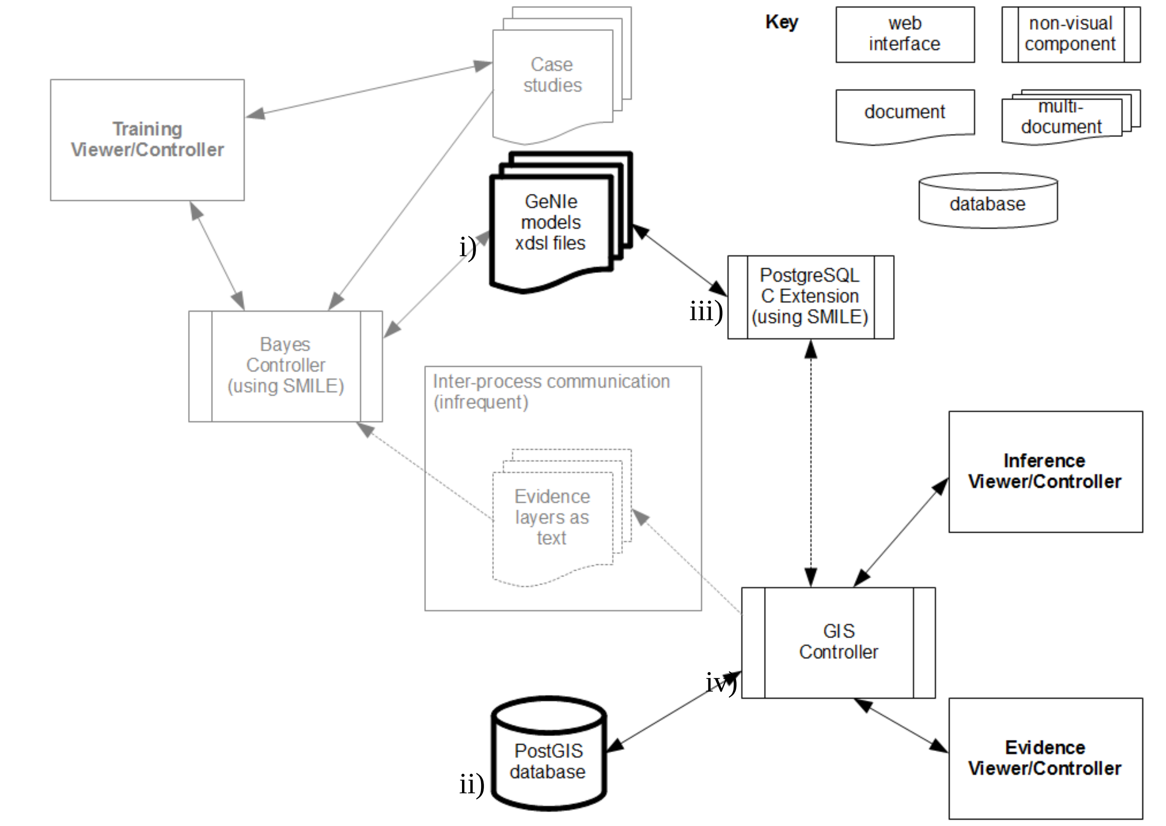

Figure 1: Components of the web-based decision support tool for Targeting AGricultural Water management Interventions (TAGMI)

The online tool is built using OpenSource software, and is available online to be used and shared freely under the conditions of the Apache License (http://www.apache.org/licenses/).

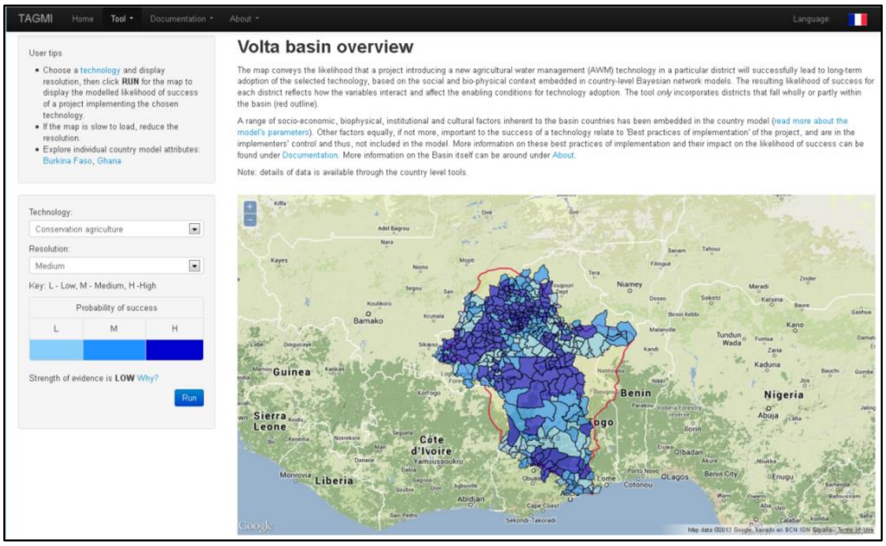

Figure 2 Screen shot of TAGMI online interface

Researchers, practitioners and farmers have identified approaches to manage rainfall for agriculture in efficient and productive ways from field to basin scales. Yet successful targeting and scaling out of appropriate interventions remains a challenge. TAGMI sets out to address this challenge, using the following rationale:

a) The targeting problem is that:
   - We want to out-scale agricultural water management (AWM) technologies
   - We want to pick sites where the chances of success are relatively good
   - A good way to decide is through rapid assessment in the field at prospective sites
b) But where to do the rapid assessments? (the pre-targeting problem):
   - Decide where conditions are promising enough that it is worth investing in a rapid field assessment
   - Only use existing and easily accessible data that is available over a large part of the basin
   - Other considerations:
     - Make it affordable
     - Build on accumulated experience and knowledge
c) Building a conceptual model to decide where conditions are promising:
   - There are factors that contribute to the success or failure of AWM technologies
     - Biophysical
     - Social and institutional
     - Technological
     - Implementation-specific
   - The factors usually cannot be observed directly, but there is indirect evidence that they are present or absent
d) Facts of life - conceptual model in practice:
   - The needed data are incomplete and imperfect
   - No model can capture all complexities of agricultural communities and their environments
   - There will be continued learning and therefore a need to update the model

MODEL STRUCTURE

The model relates observed data to an indicator of success, as shown in Figure 3. The core model is structurally simple: it relates factors of success to a success indicator. Additional model elements relate observed data (evidence) to the factors of success, and relate factors of success to the success indicator indirectly through "pseudo-factors". The model, including the additional elements, is discussed in more detail in this section.

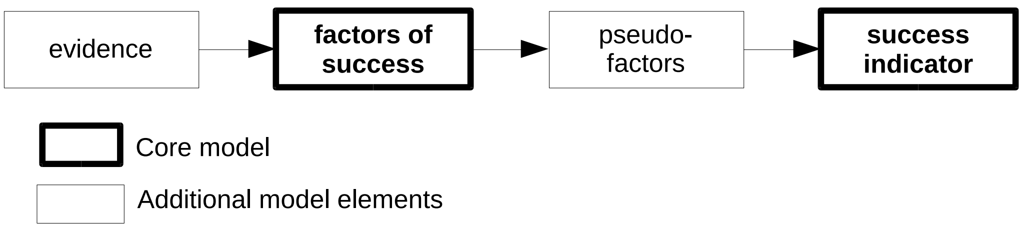

Figure 3: Model overview

The Core Model

The model is implemented as a Bayesian network (BN). The variables in such a model are discrete probability distributions, rather than fixed values; in the targeting model described in this paper the success indicator—as a Bayesian variable—takes on two possible values, "yes" and "no", and the output displayed to the user is the probability that the value of the indicator is "yes". '**Success**' is the likelihood that an AWM technology introduced in a target community will still be in use 2 years after the intervention project has ended.

Based on participants' discussions, and using the DFID Sustainable Livelihood Framework (DFID, 1999), 'Success' is conditional on adequate levels of 5 **capitals**: Human, Social, Financial, Physical and Natural. Water resources are included as a separate 6th capital given its centrality to AWM (Figure 4). A capital cannot immediately be measured using any data, but is rather described as the sum of states of a number of related resources. For example, human capital is defined as "*the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives*" (DFID 1999). Therefore, each **capital** comprises 2-4 key **factors** (e.g. Human capital is a combination of **Labour availability**, **Skills**, and **Health**). Most factors also cannot be directly measured, hence each **factor** is described by 1-3 **data variables** (e.g. **Labour availability** is indicated by the relative size of the **working age population** and the **gender ratio** in the population). The data variables are the evidence base of the model, describing the context in each district.

Relating the Data to 'Success'

The **arrows** linking data-factor, factor-capital and capital-Success convey the conditional probabilities of how each node in the network influences the presence of the next node. Using the Bayes algorithm, the model calculates the probability that the **factor** is present given knowledge about the state of its **data variable** (high, medium or low), then the probability that the **capital** is present given the calculated state of its **factors**, then the probability that **Success** is present given the calculated state of all **capitals**. A similar application of Bayesian network modelling to analyse the likelihood of water poverty is explained in detail in Kemp-Benedict et al. (2009).

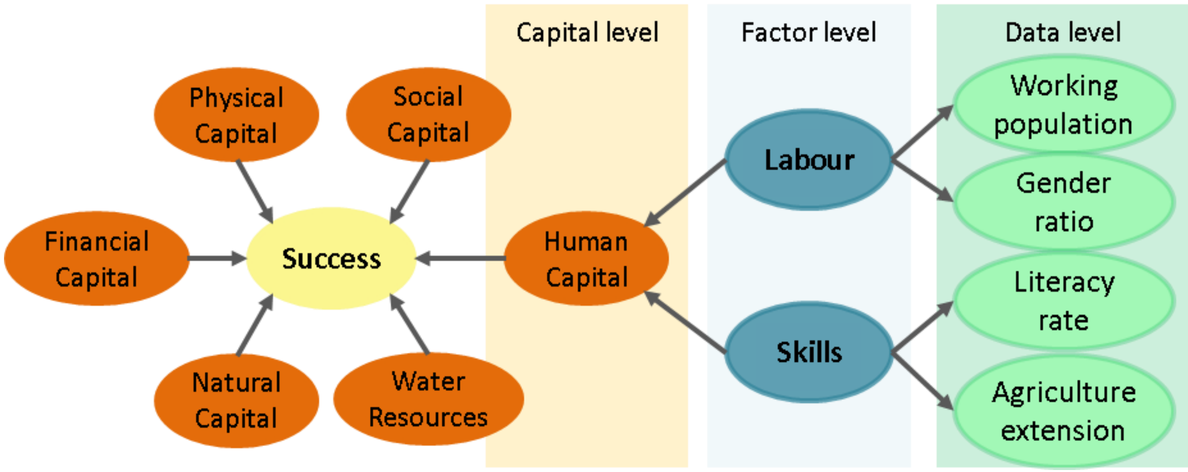

Figure 4: Conceptual model structure, showing the conditions for success (6 capitals) and the related factors and data (drawn by author)

Accounting for external factors

There are, potentially, a large number of factors contributing to the success indicator. The number of possible combinations is extremely large and it would be quite challenging for an expert to estimate the joint probability of success given all combinations of states for the factors of success. Also, the guiding assumption is that all factors of success are important (that is, we do not assume that they are substitutable, although that is a possible extension).

To reduce the cognitive burden on the expert while keeping faithful to the conceptual structure of the model, we insert, between each capital and 'Success', an intermediate "pseudo-factor" that can take one of two values—present or absent. The success indicator shows success only if all of the pseudo-factors are present, but there is a probabilistic relationship between the factors of success and the pseudo-factors; such a construct is called a "noisy-and".

The "noisy-and" also provides a leak mechanism, to account for any factor that might influence success, that has not been taken into account in the model, i.e. if all factors in the model are absent, there is still a chance (however slight) that Success can be present.

Measuring the Strength of the Data

One advantage of a Bayesian model is that not all of the evidence needs to be specified. If there is some location where one or more evidence variable is missing data, then it does not have to be set. But in that case it is important to signal that the value for the probability of success is less certain than in other locations. We do this by calculating the information entropy of the probability of success, which measures the change in the model outcome from a null state (no evidence) to an informed stated (with evidence). The result of the information entropy calculation informs the 'strength of evidence' that is displayed in the tool. This is a measure of the quality of the data used, as well as the amount of missing data. For example, if data is old, or available at a coarser geographic coverage or scale of analysis than the model is at (district-level), the evidence base for the result is weak, and the strength of evidence will be LOW. Low strength of evidence can also reflect an uncertainty in how well the data used is related to the concept it describes. Alternatively, if the data is recent, consistently representative across the country, at district level and highly relevant for all factors in the model, the evidence base for the result is strong and the strength of evidence will be HIGH.

DATA, FACTORS AND INDICATORS OF SUCCESS

The Bayesian network model is a combination of local, national and regional datasets with the expert input of our Basin project partners. The model structure was developed and populated through a series of consultations with local researchers and key stakeholders (including local government and agricultural extension agents). The initial learning event provided lists of key variables that have contributed to either the success or failure of examples of AWM technology projects from the area or region. A successful case was defined by the participants as one where the technology was still in use at least 2 years after the intervention introducing the technology had ended.

The initial list of variables was analysed and aggregated into a manageable list of main categories of factors (Table 1) which may not be directly measurable, but can be represented in part by various indicators (data variables). The potential data variables were identified and refined during the second round of consultations, where the participants gave feedback on the initial model and discussed the relationships between factors and indicators, and their importance to the likelihood of success of an AWM intervention. The conditional probabilities that define the model quantitatively are constructed from those discussions, as discussed in the next section.

Table 1: Key factors influencing the success or failure of past AWM interventions, aggregated from participants' discussions (first consultations, 2011)

Natural	Physical
Soil type, topography *	Market access *
Water availability and accessibility *	Technology design appropriate *
Water quality *	Security of technology
Soil biology	Market input/supply chain *
Biomass *	Market competition **
Microclimate	Infrastructure
Pest and weeds	
Land availability	
Human	**Social**
Willingness to engage*	Leadership (traditional, political)
Easy to understand/manage**	Leadership among adopters
Safe water quality	Actors known to client (trust)
Education level	Clear demand
Health status	Conflict *
Skills set *	Organisational responsibility /management organisation *
Labour *	Land tenure
Gender **	Culture & tradition
Wealth/poverty	
Financial	**Other – 'best practices of implementation'**
Investments assistance *	Community owns initiative **
Investment cost *	Early engagement with stakeholders
Maintenance cost *	Continuous assistance/backstopping *
Return of investments **	Direct benefit *
Access to credit	Clear demand
	Clear objective
	Appropriate design (of technology) *
	Appropriate implementation *
* mentioned for all 4 countries ** mentioned for 3 of the 4 countries	

Expert elicitation of probabilities

With sufficient data it is possible to fit the conditional probability distribution through a process called "training". However, we expect to apply the tool in model-poor environments, and so must rely on expert elicitation.

It is difficult for experts to provide complete conditional probability distributions, as the number of probabilities required is exponential to the number of variables involved and the number of states each variable can have. For example (Table 2), the conditional probability of 1 factor with 2 possible states, given 1 indicator with 3 possible states, is a combination of **6** probabilities; 1 factor with 2 possible states, given 2 indicator with 3 possible states each, is a combination of **18** probabilities; etc.:

Table 2a & b): 2 examples of conditional probability tables

a)

indicator		low	med	high
factor	yes	0.2	0.5	0.8
	no	0.8	0.5	0.2

b)

Indicator1		low			med			high		
Indicator2		low	med	high	low	med	high	low	med	high
factor	yes	0.06	0.2	0.5	0.2	0.5	0.8	0.5	0.8	0.96
	no	0.94	0.8	0.5	0.8	0.5	0.2	0.5	0.2	0.04

There are well-tested elicitation techniques, but also well-known problems with any of these techniques because of people's cognitive limitations. For this project we follow a particular approach to eliciting conditional probability distributions (Kemp-Benedict 2008).

In this approach, the expert assigns weighting factors to each of the states of the indicator (low-med-high), and also to each of the parent nodes (yes-no). Then, using a derivation of the Bayes algorithm in combination with the probability distribution of the existing data, a conditional probability table can be calculated, similar to Table 2. The tables will have a Gaussian distribution, having been mathematically generated, but can be skewed more or less from an even distribution by the weights attached to the states of the factors and indicators. This method requires far less input from the experts, and more comprehensible. The minimum input needed is to characterise two aspects of the relationship between a factor and an indicator: the *type* and the *strength*.

- the *type*:
  - If it is positive, the factor will be more likely to be **yes** when the indicator is **high**
  - If it is negative, the factor will be more likely to be **yes** when the indicator is **low**
- the strength:
  - A **strong** relationship (0.2 0.5 0.8) will be **strongly skewed** from an even distribution (0.5 0.5 0.5)
  - A **weak** relationship (0.4 0.5 0.6) will be **much closer to an even** distribution (0.5 0.5 0.5)

For detailed descriptions of the weightings defining the models, refer to Appendix A: Defining the models.

RESULTS

What do the results mean?

The results are influenced by four aspects of the model:

i) The data itself
ii) The importance of the data (designated by experts or the model designer)
iii) The importance of the factors (designated experts)
iv) The importance of the capitals (designated by the model designer, based on input from experts)

i) The data itself

The numeric data for each variable is classified into 3 categories (low-med-high), to have approximately an equal number of districts falling into each category. The thresholds therefore are statistically determined. As a result, the distribution of possible states is standardised. The exception is Mean Annual Rainfall, where thresholds were set manually using expert knowledge. The first significant impact of this approach is that the distance between thresholds depends on the range of the data, rather than on theoretical concepts, meaning that the results show relative differences across districts. For example, **Access to agricultural credit** in Burkina Faso ranges from 0 - 9%, with the equal-count thresholds at 1% and 2%. Arguably this could all be classed as *low*, but using the equal-count thresholds allows the model to differentiate those districts that have *relatively* higher **access to credit** than other districts.

The second significant impact lies within the quality of the data - many of the variables were only found for province, or even regional, scale. Where possible, in the case of proportions or averages, these coarser results have been allocated to the district level, leading to large blocks of districts with similar values. In these cases, the categories may be more skewed towards those larger blocks. For example, the classification of **rural population possessing mobile telephones** in Ghana is skewed towards the 'med' category (Table 3).

Table 3: Probability distribution of cellphone possession in Ghana (data source: Population & housing census, 2010)

	% Rural population possessing mobile telephones in Ghana (2010)	# districts	Hypothetical equal-count
low	Less than 18%	29	31
med	18 - 30%	40	32
high	More than 30%	26	32

ii) The importance of the data

The conditional probability tables linking the data to the factors they represent are based on expert input and reflect both the *type* (positive or negative) and *strength* (very strong - strong -weak) of the relationship between the data and the factor. Simply, a *very strong* relationship means higher conditional probabilities, where a *weak* relationship has conditional probabilities closer to 0.5 (an even chance of any outcome occurring). The conditional probabilities of each type of relationship with no data, or perfectly evenly distributed data are illustrated in Table 4:

Table 4: Example conditional probability table

		Access to clean drinking water								
		Very strong relation			Strong relation			Weak relation		
		low	med	high	low	med	high	low	med	high
Health	Good	0.2	0.5	0.8	0.33	0.5	0.66	0.45	0.5	0.55
	Bad	0.8	0.5	0.2	0.66	0.5	0.33	0.55	0.5	0.45

This means that data with a *very strong* relationship will have more effect on the value of the factor, and therefore contribute more to the final result, than data with a *weak* relationship. Most of the data in the current models are set to a *very strong* relationship with the factor they represent, unless expert input indicated otherwise.

iii) The importance of the factors

The value of each factor is calculated from the combined states of the data representing it. However, each factor also carries a weight that reflects how much it contributes to achieving the capital it belongs to - for example, do **Health status**, **Labour availability** and **Skills** contribute equally to achieving **Human capital**? Or is it more important to have a particular factor? These weights are provided by expert knowledge from consultations (Extremely important - Very important - Important - Somewhat important - Not important).

Weighting the factors means that a factor with a high weight will have more effect on the value of the capital, and therefore contribute more to the final result, than a factor with a low weight. An example of the effect is that a high-weight factor with a lower value may have a more positive impact on the value of the capital than a low-weight factor with a higher value.

iv) The importance of the capitals

The value of each capital is calculated from the combined, weighted states of the factors describing it. Similar to the factors, each capital also has a weight, reflecting how important that capital is to achieving long-term success of the project.

At this point in the model, the *noisy-AND* function provides an interface between the capitals and the final 'Success' which is calculated using a pure AND function, i.e. Success will only be positive if, and only if, all capitals are positive. Combined with the weighting of the capitals, this *noisy-AND* function translates the capitals into a probability that means: "If this capital is not present, how much will that reduce the likelihood of success? How necessary is this capital to the likelihood of success?" The weights used are drawn from the feedback and discussions at the consultations (Absolutely necessary - Very necessary - Necessary - Somewhat necessary - Not necessary).

For example:

a. if a capital that is *absolutely necessary* is absent, the likelihood of success will be significantly reduced;
b. however, if the capital was only *somewhat important*, the likelihood of success will not be much affected.

In another example, if all capitals are seen as *absolutely necessary*, the probability of success will be very low, because any lack in any capital will cause a significant reduction in 'Success'. On the other hand, if all capitals are seen as *not important*, the probability of success will be close to 100% - because no matter how low your level of capital is, it is not important, and therefore makes no difference to the likelihood of success.

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APPENDIX A: DEFINING THE MODELS

As described earlier, the **arrows** linking data-factor, factor-capital and capital-Success convey the conditional probabilities of how each node in the network influences the presence of the next node. Using the Bayes algorithm, the model calculates the probability that the **factor** is present given knowledge about the state of its **data variable** (high, medium or low), then the probability that the **capital** is present given the calculated state of its **factors**, then the probability that **Success** is present given the calculated state of all **capitals**. A similar application of Bayesian network modelling to analyse the likelihood of water poverty is explained in detail in Kemp-Benedict et al. (2009).

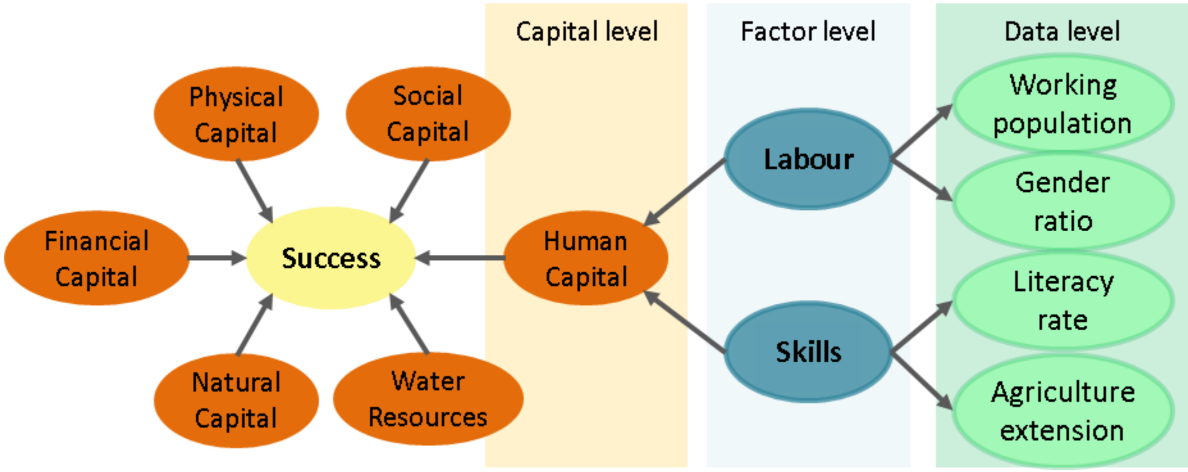

Figure 5: Conceptual model structure, showing the conditions for success (6 capitals) and the related factors and data (drawn by author)

The following tables detail the weightings used to construct the conditional probability tables (CPTs) systematically across the network, for all Volta models. These define how each node is indicative of the next in the probability chain (e.g. how does the data relate to the probable presence of the factor). In some cases we were provided with complete, detailed CPTs by experts during our consultations, but in most cases not, so a set of defaults were used, as detailed in each section.

Limpopo : Data – Factor

In the absence of detailed conditional probabilities from experts, the relationship between data and factor is a combination of *type* (positive or negative) and *strength* (strong, medium or weak):

- a *strong positive* relationship means that if the data (e.g. literacy) is high, the factor (e.g. Skills) will almost certainly be high as well (a 1:1 relationship)
- a *medium positive* relationship means that if the data is high, there is about a 70% chance that the factor will also be high
- a *weak positive* relationship means that if the data is high, there is about a 55% chance that the factor will also be high

A negative relationship simply means the factor state will be the inverse of the data state (if the data is high, the factor will be low.

Note: weightings are only shown for variables where data was available for at least one country

Thresholds give the range of the data for each category (L = Low; M = Medium; H = High). No thresholds reflects no data for that variable/country.

References reflect the source of the weighting for the relationship – is it positive/ negative/ weak/ strong. Where no reference was given in stakeholder consultations or found in literature, the researchers set the weighting.

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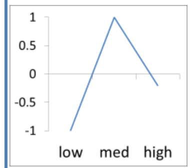

L -1
M 1
H -0.2

References:
Rusinamhodzi et al (2011) - <600 good; 600-1000 minimal; >1000 bad
Stakeholder consultations (SA)</td>
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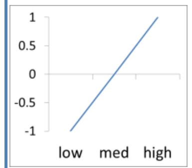

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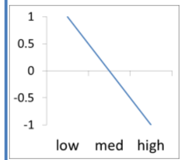

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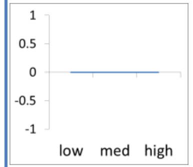

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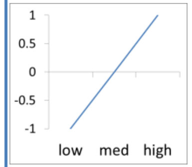

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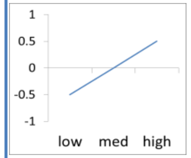
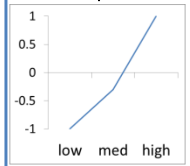
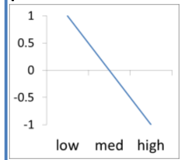
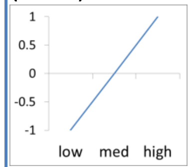
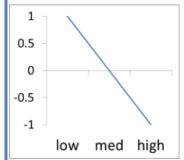
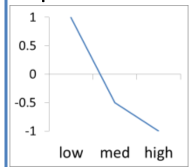
M 0
H 1</td>
<td>% district area <1km to a river


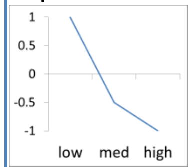
L -0.5
M 0
H 0.5</td>
</tr>
<tr>
<td>D_surfwater Thresholds:
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>0.0002-0.0008</td><td>0.009-0.038</td><td>0.001-0.002</td><td>0.004-0.028</td></tr>
<tr><td>M</td><td>0.0008-0.005</td><td>0.038-0.047</td><td>0.002-0.006</td><td>0.028-0.078</td></tr>
<tr><td>H</td><td>0.005-0.0075</td><td>0.047-0.27</td><td>0.006-0.25</td><td>0.078-1.03</td></tr>
</table></td>
<td></td>
<td>density of surface water bodies per km^2


L -1
M -0.3
H 1
Reference:
Stakeholder consults (SA)</td>
<td>density of surface water bodies per km^2


L 1
M 0
H -1</td>
</tr>
<tr>
<td>D_water_infr Thresholds (% households):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>43-72</td><td></td><td></td><td></td></tr>
<tr><td>M</td><td>72-74.5</td><td></td><td></td><td></td></tr>
<tr><td>H</td><td>74.5-87</td><td></td><td></td><td></td></tr>
</table></td>
<td></td>
<td>access to water storage (SWIs)


L -1
M 0
H 1</td>
<td>access to water storage (SWIs)


L -1
M 0
H 1</td>
</tr>
<tr>
<td>D_watertable Thresholds (mbgl):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>0-7</td><td>0-7</td><td>0-7</td><td>0-7</td></tr>
<tr><td>M</td><td>7-25</td><td>7-25</td><td>7-25</td><td>7-25</td></tr>
<tr><td>H</td><td>>25</td><td>>25</td><td>>25</td><td>>25</td></tr>
</table></td>
<td></td>
<td>depth to water table


L 1
M -0.5
H -1</td>
<td>depth to water table


L 1
M -0.5
H -1</td>
</tr>
</table>

Social Capital

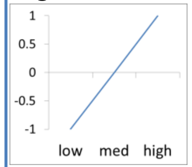
Community leadership & Organisational capacity

D_numCBOs Thresholds (#/1000HH):

	Bots	Moz	SA	Zim
L	0.1-0.3	0.4-1.5	0.6-0.78	0.02-0.03
M	0.3-0.4	1.5-4.8	0.78-1.4	0.03-0.05
H	0.4-0.6	4.8-7.8	1-4-1.6	0.05-0.08

References:
Noble et al (2006) (leadership important)

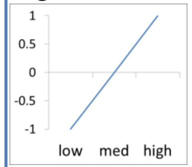
number of community organisations



L	-1
M	0
H	1

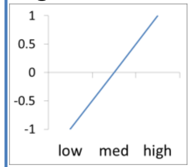
References:
Mazvimazi & Twomlow (2009) (NGOs important)

number of community organisations



L	-1
M	0
H	1

number of community organisations

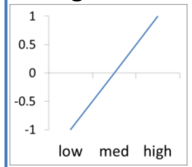


L	-1
M	0
H	1

D_voting Thresholds (%):

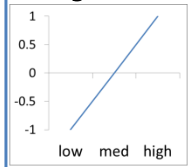
	Bots	Moz	SA	Zim
L	71-76	43-56	64-68	
M	76-79	56-60	68-76	
H	79-81	60-66	76-82	

voting turnout



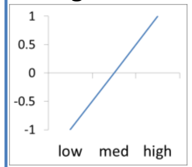
L	-1
M	0
H	1

voting turnout



L	-1
M	0
H	1

voting turnout



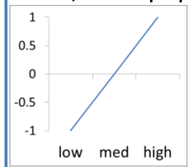
L	-1
M	0
H	1

Support network available

D_information Thresholds (%):

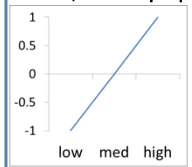
	Bots	Moz	SA	Zim
L	63-76	32.1	68-73	20-22
M	76-81		73-76	22-27
H	81-87	41.5	76-83	27-41

access to information from radio, newspaper or TV



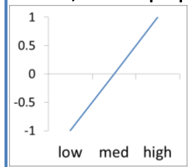
L	-1
M	0
H	1

access to information from radio, newspaper or TV



L	-1
M	0
H	1

access to information from radio, newspaper or TV

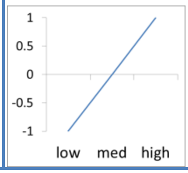


L	-1
M	0
H	1

D_remittances Thresholds (%):

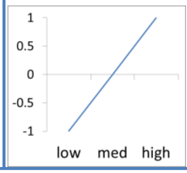
	Bots	Moz	SA	Zim
L	17-35	17	10-14	
M	35-39		14-28	
H	39-61	22	28-29	

proportion of income from remittances



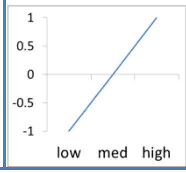
L	-1
M	0
H	1

proportion of income from remittances

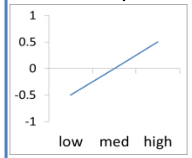


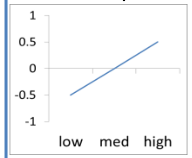
L	-1
M	0
H	1

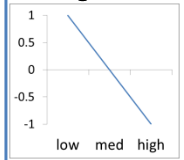
proportion of income from remittances

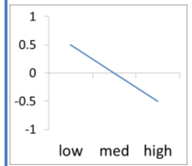


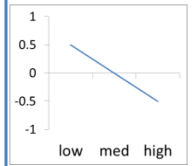
L	-1
M	0
H	1

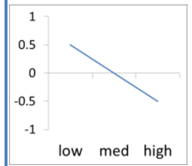
<table>
<tr><td colspan="4">Access to land</td></tr>
<tr>
<td>D_own_land Thresholds (%):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>44-61</td><td>87</td><td></td><td>40-60</td></tr>
<tr><td>M</td><td>61-64</td><td></td><td></td><td>60-70</td></tr>
<tr><td>H</td><td>64-71</td><td>92</td><td></td><td>70-85</td></tr>
</table></td>
<td>ownership of land


L -0.5
M 0
H 0.5
References:
Stakeholder consultations</td>
<td>ownership of land


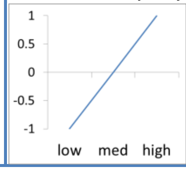
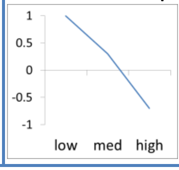
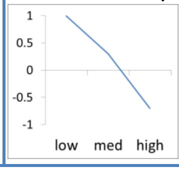
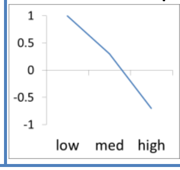
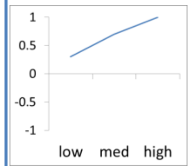
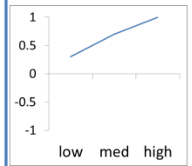
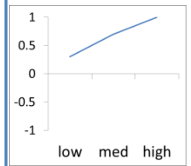
L -0.5
M 0
H 0.5
References:
Namara et al (2011)</td>
<td></td>
</tr>
<tr>
<td>D_avg_plot Thresholds (ha):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>2</td><td>0.9-1.7</td><td></td><td>2-3</td></tr>
<tr><td>M</td><td>3</td><td>1.7-1.9</td><td></td><td>3-5</td></tr>
<tr><td>H</td><td>4</td><td>1.9-2.4</td><td></td><td>5</td></tr>
</table></td>
<td>References:
Mazvimazi & Twomlow 2009</td>
<td>average farm size


L 1
M 0
H -1
References:
Stakeholder consults (Zim)</td>
<td></td>
</tr>
<tr><td colspan="4">Gendered access to resources</td></tr>
<tr>
<td>D_femHH Thresholds (%):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>32-42</td><td>37.2</td><td>30-38</td><td>33-47</td></tr>
<tr><td>M</td><td>42-45</td><td></td><td>38-45</td><td>47-63</td></tr>
<tr><td>H</td><td>45-57</td><td>47.2</td><td>45-59</td><td>63-70</td></tr>
</table></td>
<td>proportion of female-headed households


L 0.5
M 0
H -0.5
References:
Mazvimazi & Twomlow (2009) - Gender only significant to 10%</td>
<td>proportion of female-headed households


L 0.5
M 0
H -0.5
Reference:
Research team – evidence from literature suggests a negative relationship, but conflicting results suggest it to be a weak relationship</td>
<td>proportion of female-headed households


L 0.5
M 0
H -0.5
Reference:
Research team – evidence from literature suggests a negative relationship, but conflicting results suggest it to be a weak relationship</td>
</tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

D_gemployment Thresholds (women:men): Bots / Moz / SA / Zim L: 0.6-0.8 / 0.93 / / 0.14-1.24 M: 0.8-0.9 / / / 1.24-1.3 H: 0.9-1 / 0.95 / / 1.3			female employment rate  L -1 M 0 H 1
Financial capital			
Wealth			
D_poverty Thresholds (%): Bots / Moz / SA / Zim L: 12-18 / 50-64 / 43-51 / 45-74 M: 18-20 / 64-89 / 51-61 / 74-81 H: 20-40 / 89-95 / 61-70 / 81-96	incidence of poverty  L 1 M 0.3 H -0.7	incidence of poverty  L 1 M 0.3 H -0.7	incidence of poverty  L 1 M 0.3 H -0.7
Access to credit			
D_availMFIs Thresholds (#/1000 HH): Bots / Moz / SA (%) / Zim L: / 1 / 14-14.5 / 0.004-0.008 M: / / 14.5-24 / 0.008-0.011 H: / 2.4 / 24-31 / 0.011-0.02	availability of micro-finance institutions  L 0.3 M 0.7 H 1 References: Stakeholder consults (Zim)	availability of micro-finance institutions  L 0.3 M 0.7 H 1 References: Stakeholder consultations Namara et al (2011) - land tenure security	availability of micro-finance institutions  L 0.3 M 0.7 H 1

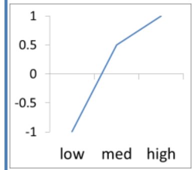
Human capital

Health status

D_wsafe Thresholds (%):

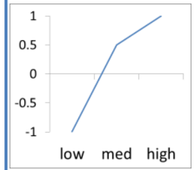
	Bots	Moz	SA	Zim
L	91-94	50-80	71-93	25-56
M	94-99.9	80-90	93-97	56-80
H	99.9-100	90-97	97-100	80-86

households with safe drinking water



L	-1
M	0.5
H	1

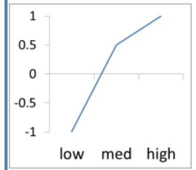
households with safe drinking water



L	-1
M	0.5
H	1

Reference:
Stakeholder consults (SA)

households with safe drinking water



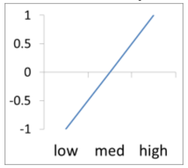
L	-1
M	0.5
H	1

References:
Stakeholder consults (Zim)

D_food_sec Thresholds (%):

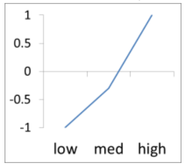
	Bots	Moz	SA	Zim
L		35-74	82-90	72-80
M	79-93	74-82	90-93	80-89
H	93-99	82-89	93-99	89-96

food security level



L	-1
M	0
H	1

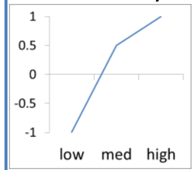
food security level



L	-1
M	-0.3
H	1

Reference:
Stakeholder consults (SA)

food security level



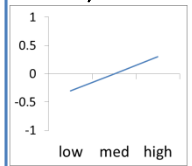
L	-1
M	0.5
H	1

References:
Stakeholder consults (Zim)

D_clinics Thresholds (#/1000HH):

	Bots	Moz	SA	Zim
L		0-0.25	0.14-0.23	
M		0.25-0.5	0.23-0.33	
H		0.5-1.2	0.33-0.45	

density of clinics



L	-0.3
M	0
H	0.3

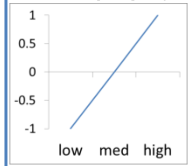
Reference:
Stakeholder consults (SA)

Labour availability

D_work_pop Thresholds (% 15-65):

	Bots	Moz	SA	Zim
L	28-33	47-49	52-57	52-53
M	33-40	49-51	57-63	53-55
H	40-51	51-57	63-70	55-57

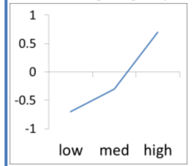
working age population



L	-1
M	0
H	1

References:
Stakeholder consults (Zim)

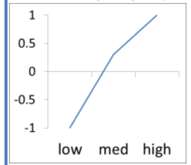
working age population



L	-0.7
M	-0.3
H	0.7

References:
Stakeholder consults (SA, Zim)

working age population



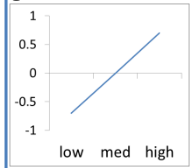
L	-1
M	0.3
H	1

References:
Stakeholder consults (Zim)

D_g_ratio Thresholds (women:men):

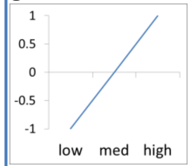
	Bots	Moz	SA	Zim
L	0.97-1.06	1.08-1.24	0.82-0.98	0.85-1.05
M	1.06-1.08	1.24-1.26	0.98-1.14	1.05-1.11
H	1.08-1.16	1.26-1.33	1.14-1.27	1.11-1.18

gender ratio



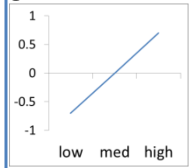
L	-0.7
M	0
H	0.7

gender ratio



L	-1
M	0
H	1

gender ratio

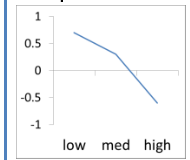


L	-0.7
M	0
H	0.7

D_HIV Thresholds (%):

	Bots	Moz	SA	Zim
L	15-dec	10	14-26	15-19
M	15-18		26-32	19-21
H	18-27	29.9	32-47	21

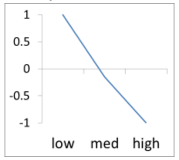
HIV prevalence



L	0.6
M	0.3
H	-0.6

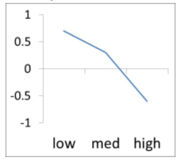
References:
Stakeholder consults (Zim)

HIV prevalence



L	1
M	-0.15
H	-1

HIV prevalence



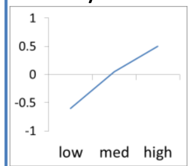
L	0.6
M	0.3
H	-0.6

Skills (education and training)

D_literacy Thresholds (%):

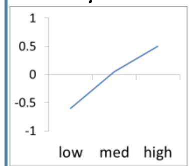
	Bots	Moz	SA	Zim
L	75-79	39-53	45-54	86-95
M	79-92	53-61	54-61	95-95
H	92-95	61-70	61-70	95-96

literacy rate



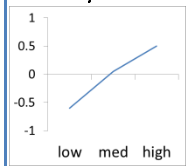
L	-0.6
M	0.05
H	0.5

literacy rate



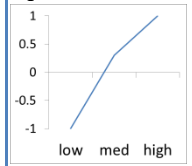
L	-0.6
M	0.05
H	0.5

literacy rate



L	-0.6
M	0.05
H	0.5

References:
Stakeholder consults (Zim)

<table>
<tr>
<td>D_ag_ext Thresholds (%):
<table><tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr><tr><td>L</td><td>0.6-0.8</td><td>4.6</td><td>46-51</td><td></td></tr><tr><td>M</td><td>0.8-1.0</td><td></td><td>51-70</td><td></td></tr><tr><td>H</td><td>1.0-1.2</td><td></td><td>70-71</td><td></td></tr></table></td>
<td>agricultural extension services

L -1
M 0.3
H 1
References:
Stakeholder consults (Zim)
Mazvimazi & Twomlow (2009)</td>
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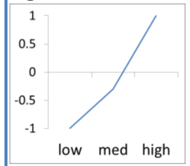
L -1
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Stakeholder consults (SA - % farmers trained)</td>
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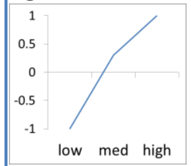
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M 0.3
H 1</td>
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<td>D_employment Thresholds (%):
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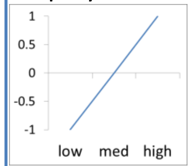
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M 0
H 1</td>
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<tr><td colspan="4">Physical capital</td></tr>
<tr><td colspan="4">Physical infrastructure</td></tr>
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<td>D_prox_rd Thresholds (%):
<table><tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr><tr><td>L</td><td>63-78</td><td>5-27</td><td>38-53</td><td>36-61</td></tr><tr><td>M</td><td>78-89.5</td><td>27-55</td><td>53-69</td><td>76.5</td></tr><tr><td>H</td><td>89.5-100</td><td>55-100</td><td>69-96</td><td>76.5-89</td></tr></table></td>
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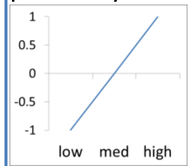
L -1
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Stakeholder consults (Zim, SA)</td>
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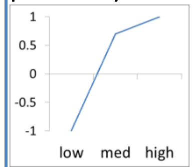
L -1
M 0.7
H 1
References:
Stakeholder consults (SA)
Namara et al (2011)</td>
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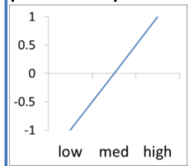
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M 0
H 1</td>
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<tr><td>L</td><td>4-28</td><td>1.1</td><td></td><td>32-40</td></tr>
<tr><td>M</td><td>28-32</td><td></td><td></td><td>40-51</td></tr>
<tr><td>H</td><td>32-40</td><td>9.3</td><td></td><td>51</td></tr>
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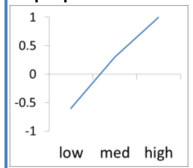

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References:
Stakeholder consults (Zim)</td>
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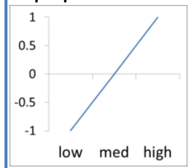

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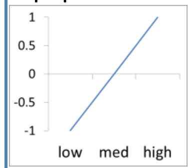

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<tr><td colspan="4">Access to markets</td></tr>
<tr>
<td>D_market Thresholds (hrs):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>0-1</td><td>0-4</td><td>1-2</td><td>1-2.9</td></tr>
<tr><td>M</td><td>1-3.25</td><td>4-8</td><td>2-3.5</td><td>2.9-5</td></tr>
<tr><td>H</td><td>3.25-4.2</td><td>8-14</td><td>3.5-6</td><td>5-8.5</td></tr>
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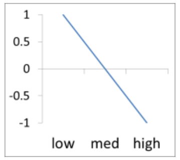
<td>distance to the nearest market town


<table><tr><td>L</td><td>1</td></tr><tr><td>M</td><td>0</td></tr><tr><td>H</td><td>-1</td></tr></table></td>
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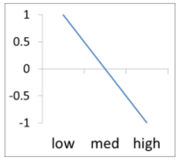

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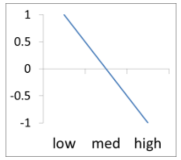

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<tr>
<td>D_cell_net Thresholds (%):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>52-71</td><td>0.1-0.3</td><td>66-71</td><td></td></tr>
<tr><td>M</td><td>71-89</td><td>0.3-0.5</td><td>71-75</td><td></td></tr>
<tr><td>H</td><td>89-95</td><td>0.5-2.1</td><td>75-83</td><td></td></tr>
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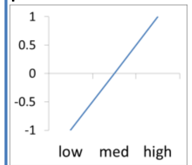

<table><tr><td>L</td><td>-1</td></tr><tr><td>M</td><td>0</td></tr><tr><td>H</td><td>1</td></tr></table></td>
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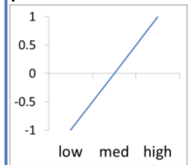

<table><tr><td>L</td><td>-1</td></tr><tr><td>M</td><td>0</td></tr><tr><td>H</td><td>1</td></tr></table></td>
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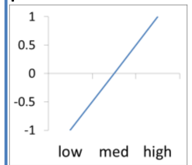

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<td>D_transport Thresholds (%):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td></td><td>6-21</td><td></td><td></td></tr>
<tr><td>M</td><td></td><td>21-38</td><td></td><td></td></tr>
<tr><td>H</td><td></td><td>38-69</td><td></td><td></td></tr>
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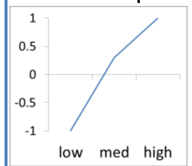
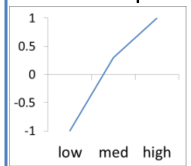
<td>have transportation


<table><tr><td>L</td><td>-1</td></tr><tr><td>M</td><td>0.3</td></tr><tr><td>H</td><td>1</td></tr></table>
References:
Stakeholder consults (SA)</td>
<td>have transportation


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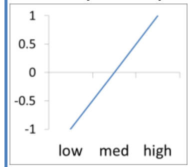
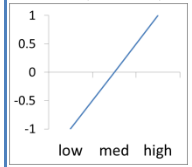
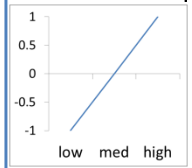
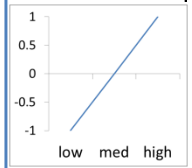
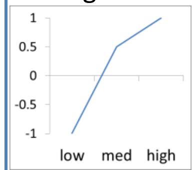
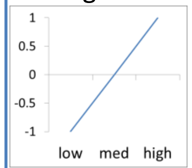
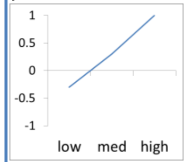
D_input_market Thresholds: Bots / Moz / SA / Zim L 20-21 M 21-23 H 23-34	density of input markets  L -1 M 0 H 1 References: Stakeholder consults (SA)	density of input markets  L -1 M 0 H 1	
D_output_market Thresholds (# populated places 1000km^{-2}): Bots / Moz / SA / Zim L 0. 2-0. 9 / 0. 2-0. 6 / 0. 3-0. 5 / 0. 4-1.1 M 0. 9-5 / 0. 6-1.7 / 0. 5-1.1 / 1.1-2 H 5-19 / 1.7-19 / 1.1-140 / 2-11	number of output markets  L -1 M 0 H 1 References: Stakeholder consults (SA)	number of output markets  L -1 M 0 H 1	
Natural capital			
Soil suitability for agriculture			
D_SOC Thresholds (% district with high SOC): Bots / Moz / SA / Zim L 21-68 / 77-96 / 5-55 / 0.98-17 M 68-80 / 96-99 / 55-85 / 17-30.2 H 80-99 / 99-100 / 85-100 / 30.2-68.3	soil organic carbon content  L -1 M 0.5 H 1 References: Stakeholder consults (SA)	soil organic carbon content  L -1 M 0 H 1	

D_clay Thresholds (% district with high clay content):

	Bots	Moz	SA	Zim
L	41-84	3-30	10-14	0.5-3.4
M	84-97	30-42	14-50	3.4-7.2
H	97-99	42-70	50-100	7.2-50.5

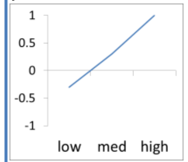
presence of clay in the topsoil



L	-0.3
M	0.3
H	1

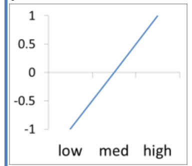
References:
Stakeholder consults (Zim)

presence of clay in the topsoil



L	-0.3
M	0.3
H	1

presence of clay in the topsoil



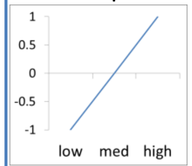
L	-1
M	0
H	1

Land availability for agriculture

D_cropland Thresholds (ha):

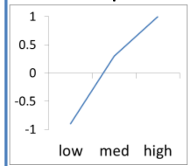
	Bots	Moz	SA	Zim
L	523-2658	158-8361	2648-73917	1210-40975
M	2658-15944	8361-19473	73917-196949	40975-68025
H	15944-174485	19473-54848	196949-847739	68025-170170

total cropland area



L	-1
M	0
H	1

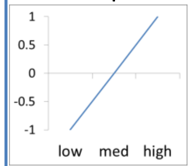
total cropland area



L	-0.9
M	0.3
H	1

References:
Stakeholder consults (Zim)

total cropland area

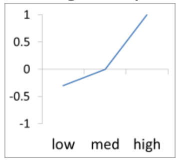


L	-1
M	0
H	1

D_slope Thresholds (% district with flat land):

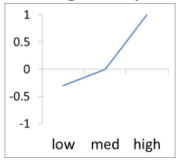
	Bots	Moz	SA	Zim
L			73-80	
M			80-90	
H	91-100	97-100	90-100	99-100

average slope



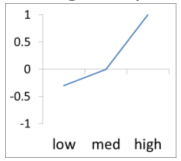
L	-0.3
M	0
H	1

average slope



L	-0.3
M	0
H	1

average slope

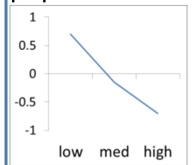


L	-0.3
M	0
H	1

D_pop_dens Thresholds (# people km^{-2}):

	Bots	Moz	SA	Zim
L	4-10	1-4	20-50	8-12
M	10-728	4-34	50-75	12-14
H	728-1135	34-865	75-540	14-37

population density



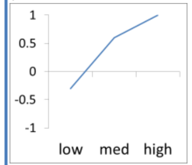
L	0.7
M	-0.15
H	-0.7

Biomass availability for agriculture

D_bio_prod Thresholds:

	Bots	Moz	SA	Zim
L	0.08-0.64	1.45-1.9	0.04-0.95	0.77-1.65
M	0.64-1.06	1.9-2.5	0.95-1.55	1.65-1.99
H	1.06-1.32	2.5-3	1.55-2.6	1.99-2.8

potential biomass production



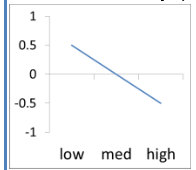
L	-0.3
M	0.7
H	1

References:
Stakeholder consults (Zim)

D_cattle_dens Thresholds (head km^{-2}):

	Bots	Moz	SA	Zim
L	2-11	0-2	2-12	2-7
M	11-12	2-6	12-19	7-15
H	12-30	6-47	19-23	15-20

cattle density (head/km2)



L	0.5
M	0
H	-0.5

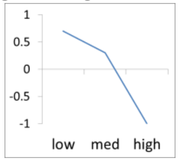
References:
Stakeholder consults (Zim)

Weather variability

D_dryspells Thresholds:

	Bots	Moz	SA	Zim
L	1809-2136	15-2077	1384-1904	1988-2218
M	2136-2382	2077-2346	1904-2274	2218-2375
H	2382-2628	2346-2628	2274-2346	2375-2601

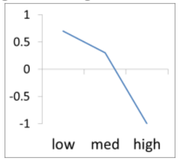
likelihood of dry spells during growing season



L	0.7
M	0.3
H	-1

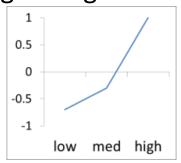
References:
Stakeholder consults (Zim)

likelihood of dry spells during growing season

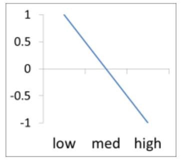


L	0.7
M	0.3
H	-1

likelihood of dry spells during growing season



L	-0.7
M	-0.3
H	1

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Agricultural pests and diseases</td></tr>
<tr>
<td>D_loss_prod Thresholds (%):
<table>
<tr><td></td><td>Bots</td><td>Moz</td><td>SA</td><td>Zim</td></tr>
<tr><td>L</td><td>4-10</td><td></td><td></td><td></td></tr>
<tr><td>M</td><td>10-18</td><td></td><td></td><td></td></tr>
<tr><td>H</td><td>18-22</td><td></td><td></td><td></td></tr>
</table>
</td>
<td></td>
<td>References:
Namara et al (2011)</td>
<td>loss of harvest to pests or disease


L 1
M 0
H -1
References:
Stakeholder consults (SA)</td>
</tr>
</table>

Limpopo : Factor – Capital

How important is a high level of the *factor* (e.g. Water availability for agriculture) to achieving a high level of the *capital* (e.g. Water resources)? Where:

4 = Essential; 3 = Very important; 2 = Important; 1 = Somewhat important; 0 = Not important

	Conservation Agriculture	Small scale irrigation	Small reservoirs
Water availability	4	4	4
Water access	4	4	4
Water quality	0	3	4
Organisational capacity	3	4	4
Support network	3	3*	3*
Land access	3	4	3
Conflict	3	4	0
Gender	3	4	2
Wealth	3*	3*	4*
Credit access	3	3	4
Health	3	3	3
Labour availability	4	3	3
Skills	4	4	3
Infrastructure	4	4	4
Market access	3	4	1
Soil suitability	4	3	4
Land availability	4	4	2
Biomass	4	0	0
Extreme Weather*	3*	3*	-
Weeds and pests	2	0	0
* No weight given by workshop participants, so value assigned by modeller			

Limpopo : Capital – Success

How necessary is the *capital* (e.g. Water resources) for successful projects? Where:

4 = Essential (the project will certainly fail without it); 3 = Important; 2 = Somewhat Important; 1= Not important (its presence or absence will make no difference to the likelihood of success)

	Conservation Agriculture	Small scale irrigation	Small reservoirs
Water resources	4	4	4
Social capital	3	4	3
Financial capital	3	3	4
Human capital	3	3	3
Physical capital	3	4	3
Natural capital	4	3	3

Limpopo : Data missing

* denotes data is missing

	Botswana	Mozambique	South Africa	Zimbabwe
Water resources				
Water availability for agriculture				
mean annual rainfall (mm)				
Water accessibility for agriculture				
% district area <1km to a river				
depth of water table				
access to surface water				
access to water storage infrastructure		*	*	*
possession of water permits	*	*	*	*
Water quality for agriculture				
salinity of water	*	*	*	*
Social Capital				
Community leadership & Organisational capacity				
number of community organisations				
voting turnout (%)				*
number of conflicting interest groups	*	*	*	*
number of disputes managed	*	*	*	*
Support network available				
access to information from radio, newspaper or television				
proportion of income from remittances				*
Access to land				
ownership of land			*	
average farm size			*	
Gendered access to resources				
proportion of female-headed households				
female employment rate			*	
women's access to assets	*	*	*	*
Financial capital				
Wealth				
incidence of poverty				
Access to credit				
availability of micro-finance institutions	*			
Human capital				
Health status				
households with safe drinking water				

	Botswana	Mozambique	South Africa	Zimbabwe
food insecurity level				
density of clinics	*			*
Labour availability				
working age population (15-65)				
gender ratio (women:men)				
HIV prevalence				
Skills (education and training)				
literacy rate				
agricultural extension services				*
use of soil management practices	*	*	*	*
employment rate			*	
Physical capital				
Physical infrastructure				
proximity to a road				
access to agricultural equipment			*	
post-harvest infrastructure available	*	*	*	*
Access to markets				
distance to the nearest market town				
possession of cellphones				*
density of input markets		*	*	*
density of output markets				
have transportation	*			*
Natural capital				
Soil suitability for agriculture				
soil organic carbon content				
presence of clay loam in the district				
Land availability for agriculture				
total cropland area				
average slope				
population density				
Biomass availability for agriculture				
potential biomass production				
cattle density (head/km2)				
Weather variability				
incidence of dry spells during growing season				
Agricultural pests and diseases				
loss of harvest to pests or disease		*	*	*

Volta : Data - Factor

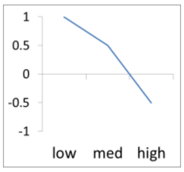
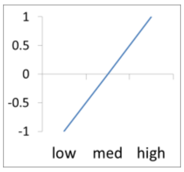
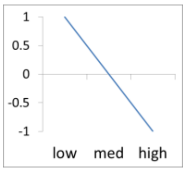
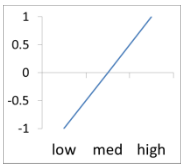
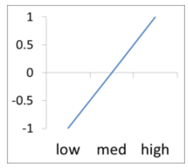
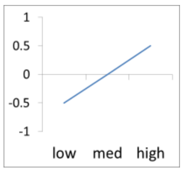
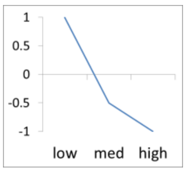
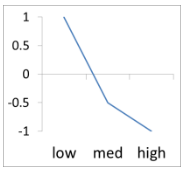
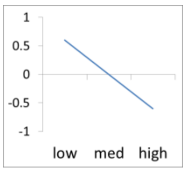
In the absence of detailed conditional probabilities from experts, the relationship between data and factor is a combination of *type* (positive or negative) and *strength* (strong, medium or weak):

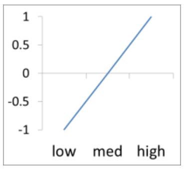
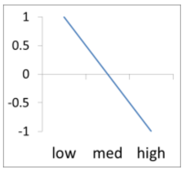
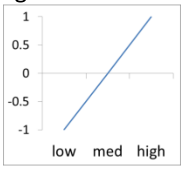
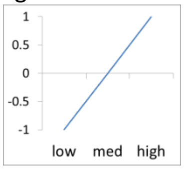
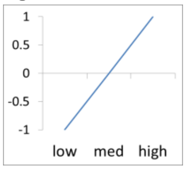
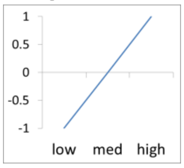
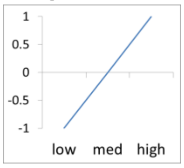
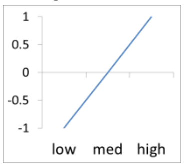
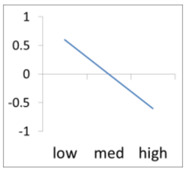
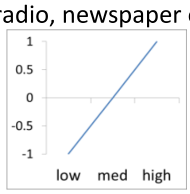
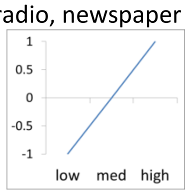
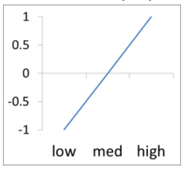
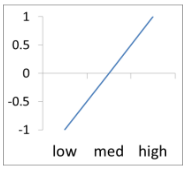
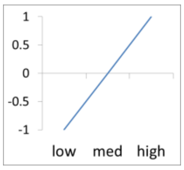
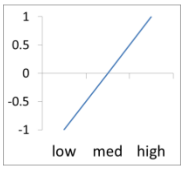
- a *strong positive* relationship means that if the data (e.g. literacy) is high, the factor (e.g. Skills) will almost certainly be high as well (a 1:1 relationship)
- a *medium positive* relationship means that if the data is high, there is about a 70% chance that the factor will also be high
- a *weak positive* relationship means that if the data is high, there is about a 55% chance that the factor will also be high

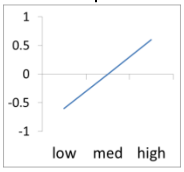
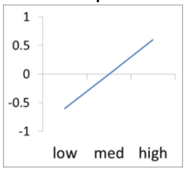
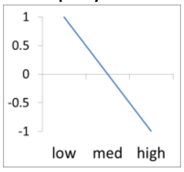
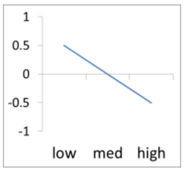
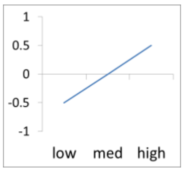
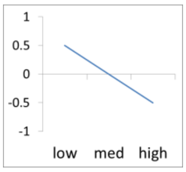
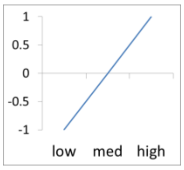
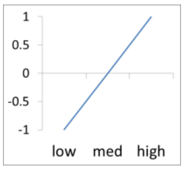
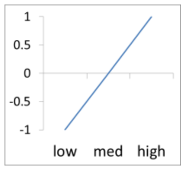
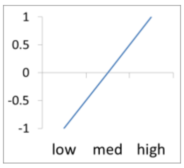
A negative relationship simply means the factor state will be the inverse of the data state (if the data is high, the factor will be low.

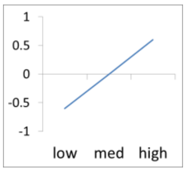
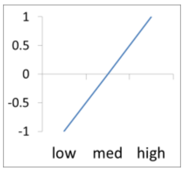
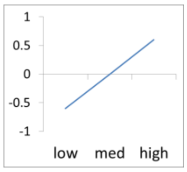
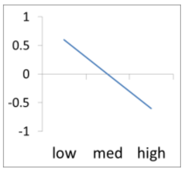
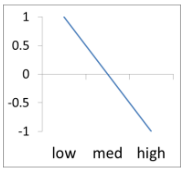
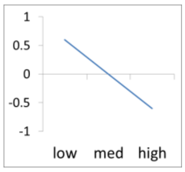
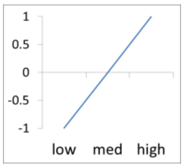
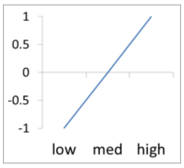
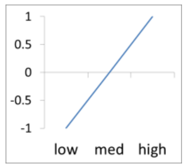
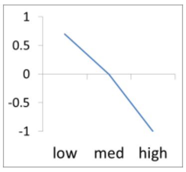
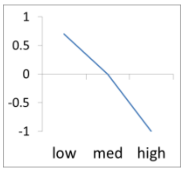
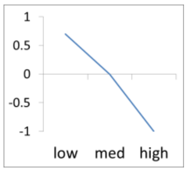
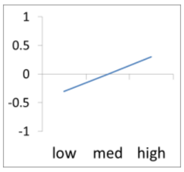
Note: weightings are only shown for variables where data was available for at least one country **Thresholds** give the range of the data for each category (L = Low; M = Medium; H = High). No thresholds reflects no data for that variable/country.

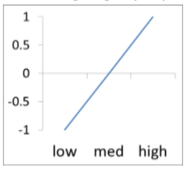
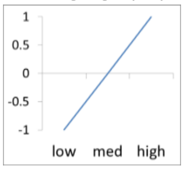
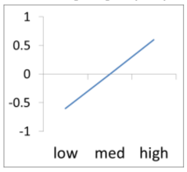
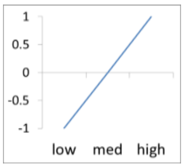
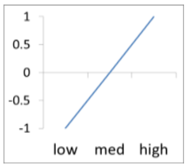
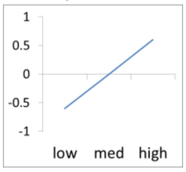
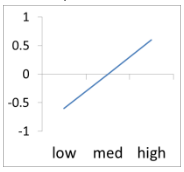
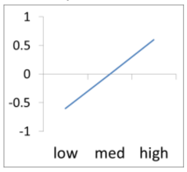
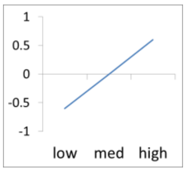
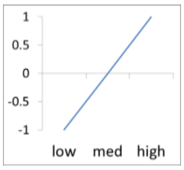
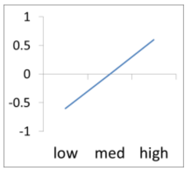
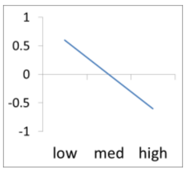
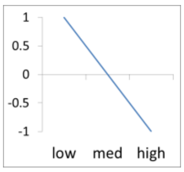
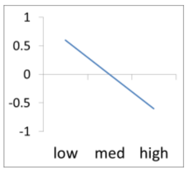
References reflect the source of the weighting for the relationship – is it positive/ negative/ weak/ strong. Where no reference was given in stakeholder consultations or found in literature, the researchers set the weighting.

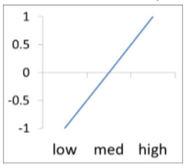
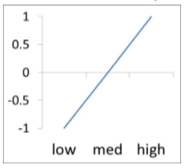
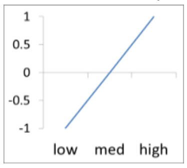
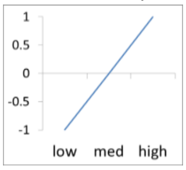
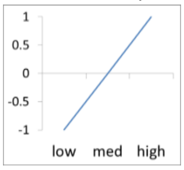
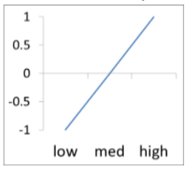
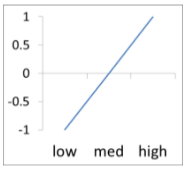
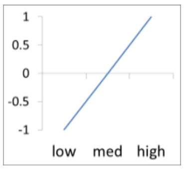
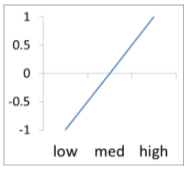
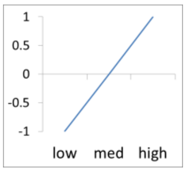
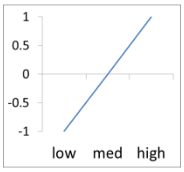
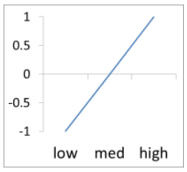
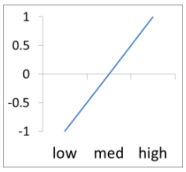
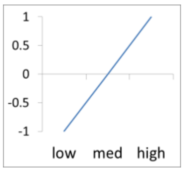
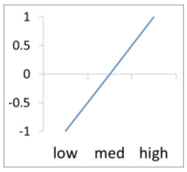
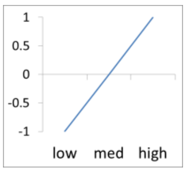
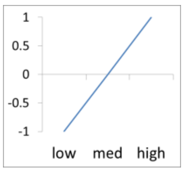
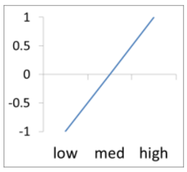
	SWC	Irrigation	Small Reservoirs
		Water resources	
Water availability for agriculture			
D_MAR Thresholds (mm): BF / GH L 200-750 / 200-750 M 750-1200 / 750-1200 H >1200 / >1200	mean annual rainfall  L 1 M 0.5 H -0.5 Reference: Mati et al 2006	mean annual rainfall  L -1 M 0 H 1	mean annual rainfall  L 1 M 0 H -1
Water accessibility for agriculture			
D_prox_riv Thresholds (%): BF / GH L 0-12 / 0-14.4 M 12-18.2 / 14.4-22.2 H 18.2-40 / 22.2-33	% district area <1km to a river  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	% district area <1km to a river  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	% district area <1km to a river  L -0.5 M 0 H 0.5
D_watertable Thresholds (mbgl): BF / GH L 0-7 / 0-7 M 7-25 / 7-25 H >25 / >25	depth to water table  L 1 M -0.5 H -1	depth to water table  L 1 M -0.5 H -1	depth to water table  L 0.6 M 0 H -0.6 Reference: Stakeholder consults (BF)

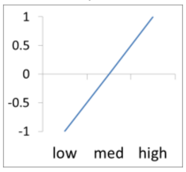
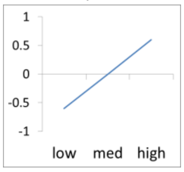
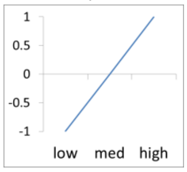
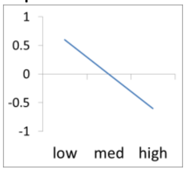
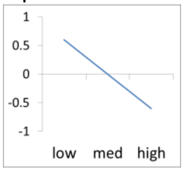
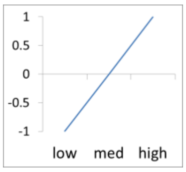
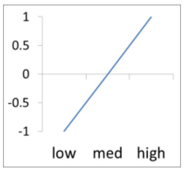
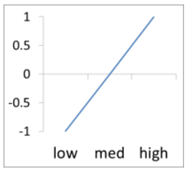
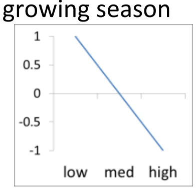
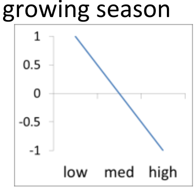
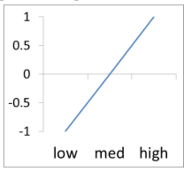
	SWC	Irrigation	Small Reservoirs
D_surfwater Thresholds (# water bodies km^{-2}): BF / GH L 0-0.0025 / 0-0.008 M 0.0025-0.01 / 0.008-0.014 H 0.01-0.07 / 0.014-0.6		access to surface water  L -1 M 0 H 1	access to surface water  L 1 M 0 H -1 Reference: Stakeholder consults (BF)
Social Capital			
Community leadership & Organisational capacity			
D_numCBOs Thresholds (#/1000HH): BF / GH L 9.8-19.2 / 0.04-0.06 M 19.2-22.2 / 0.06-0.07 H 22.2-43.5 / 0.07-0.12	number of community organisations  L -1 M 0 H 1 Reference: Noble et al (2006)	number of community organisations  L -1 M 0 H 1	number of community organisations  L -1 M 0 H 1
D_voting Thresholds (%): BF / GH L 54-73 / 58-60.3 M 73-76.3 / 60.3-64.2 H 76.3-84 / 64.2-65.1	voting turnout  L -1 M 0 H 1	voting turnout  L -1 M 0 H 1	voting turnout  L -1 M 0 H 1
D_cattle_dens Thresholds (head km^{-2}): BF / GH L 5-21 / 0-2.5 M 21-30.9 / 2.5-6.9 H 30.9-102 / 6.9-36			ratio of pastoralists  L 0.6 M 0 H -0.6 Reference: Stakeholder consults (BF)
Support network available			
D_information Thresholds (% households): BF / GH L 33-41.8 / 61-70.1 M 41.8-50.5 / 70.1-84.8 H 50.5-60 / 84.8-92	access to information from radio, newspaper or TV  L -1 M 0 H 1	access to information from radio, newspaper or TV  L -1 M 0 H 1	access to information from radio, newspaper or TV  L -1 M 0 H 1
D_remittances Thresholds (% households): BF / GH L / 2-5.4 M / 5.4-6.4 H / 6.4-16.1	income from remittances  L -1 M 0 H 1	income from remittances  L -1 M 0 H 1	income from remittances  L -1 M 0 H 1

	SWC	Irrigation	Small Reservoirs
Access to land			
D_own_land Thresholds (%): BF GH L 67-90.2 4-7 M 90.2-93.2 7 H 93.2-98 7-15		ownership of land  L -0.6 M 0 H 0.6 Reference: Stakeholder consults (GH)	ownership of land  L -0.6 M 0 H 0.6 Reference: Stakeholder consults (GH)
Reduced Conflict			
D_unemploy Thresholds (%): BF GH L 0.3-0.94 M 0.94-2.14 H 2.14-2.3	unemployment rate  L 1 M 0 H -1 Reference: Stakeholder consults (GH)		
Gender			
D_femHH Thresholds (%): BF GH L 4-7.6 14-27.7 M 7.6-10.2 27.7-36.8 H 10.2-13 36.8-39	female-headed households  L 0.5 M 0 H -0.5 Reference: Djurfeldt et al (2013)	female-headed households  L -0.5 M 0 H 0.5 Reference: Shamon & Naifeh (2013)	female-headed households  L 0.5 M 0 H -0.5 Reference: Djurfeldt et al (2013)
D_g_credit Thresholds (women:men): BF GH L 0.45-0.6 M 0.6-0.66 H 0.66-0.85	women's access to credit  L -1 M 0 H 1 Reference: Djurfeldt et al (2013)	women's access to credit  L -1 M 0 H 1 Reference: Djurfeldt et al (2013)	women's access to credit  L -1 M 0 H 1 Reference: Djurfeldt et al (2013)
D_g_ratio Thresholds (women:men): BF GH L 0.8-1 M 1-1.05 H 1.05-1.2	gender ratio  L -1 M 0 H 1 Reference: Stakeholder consults (GH)		

	SWC	Irrigation	Small Reservoirs
Financial capital			
Access to credit			
D_avail_MFI Thresholds (#/1000 HH): BF / GH L 0-0.9 / 0.04-0.06 M 0.9-2.1 / 0.06-0.07 H 2.1-8.2 / 0.07-0.12	availability of microfinance institutions  L -0.6 M 0 H 0.6 Reference: Stakeholder consults (GH)	availability of microfinance institutions  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	availability of microfinance institutions  L -0.6 M 0 H 0.6
Wealth			
D_poverty Thresholds(% poor): BF / GH L 22-41 / 7.5-32.5 M 41-58.6 / 32.5-57.07 H 58.6-69 / 57.07-89	poverty level  L 0.6 M 0 H -0.6	poverty level  L 1 M 0 H -1	poverty level  L 0.6 M 0 H -0.6
Human capital			
Skills (education and training)			
D_wsafe Thresholds (%): BF / GH L 30-84 / 62-67 M 84-109 / 67-77 H 109-202 / 77-97	household with safe water  L -1 M 0 H 1	household with safe water  L -1 M 0 H 1	household with safe water  L -1 M 0 H 1
D_malnut Thresholds: BF / GH L 23 / 14-26.5 M / 26.5-32.4 H 57 / 32.4-38	incidence of malnutrition  L 0.7 M 0 H -1 Reference: Stakeholder consults	incidence of malnutrition  L 0.7 M 0 H -1 Reference: Stakeholder consults	incidence of malnutrition  L 0.7 M 0 H -1 Reference: Stakeholder consults
D_clinics Thresholds (#/1000 HH): BF / GH L 0.03-0.1 / 0.29-0.47 M 0.1-0.12 / 0.47-0.76 H 0.12-0.17 / 0.76-1.2		density of clinics  L -0.3 M 0 H 0.3 Reference: Stakeholder consults (GH)	

	SWC	Irrigation	Small Reservoirs
Labour availability			
D_work_pop Thresholds (%): BF / GH L 46-47 / 29-32.9 M 47-48 / 32.9-34.4 H 48-62 / 34.4-36	working age population  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	working age population  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	working age population  L -0.6 M 0 H 0.6
D_g_ratio Thresholds (women:men): BF / GH L 0.9-1.05 / 0.8-1 M 1.05-1.14 / 1-1.05 H 1.14-1.5 / 1.05-1.2		gender ratio  L -1 M 0 H 1	gender ratio  L -1 M 0 H 1 Reference: Stakeholder consults (BF)
Skills (education and training)			
D_literacy Thresholds (%): BF / GH L 15.9-19.5 / 32-40 M 19.5-26.9 / 40-70 H 26.9-63 / 70-89	literacy rate  L -0.6 M 0 H 0.6 Reference: Stakeholder consults (GH)	literacy rate  L -0.6 M 0 H 0.6 Reference: Stakeholder consults (GH)	literacy rate  L -0.6 M 0 H 0.6
	Physical capital		
Physical infrastructure			
D_prox_rd Thresholds (% district within 5km of a road): BF / GH L 0-60.5 / 0-62.3 M 60.5-76.7 / 62.3-79.1 H 76.7-100 / 79.1-100	proximity to a road  L -0.6 M 0 H 0.6 Reference: Stakeholder consults (GH)	proximity to a road  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	proximity to a road  L -0.6 M 0 H 0.6 Reference: Stakeholder consult (GH, BF)
D_equipment Thresholds (% households): BF / GH L 14-39.6 M 39.6-48.1 H 48.1-54		access to agricultural equipment  L -1 M 0 H 1	
Access to markets			
D_market Thresholds (hrs): BF / GH L 0-1.5 / 0-1.75 M 1.5-2.1 / 1.75-2.7 H 2.1-12.2 / 2.7-7.8	distance to nearest market  L 0.6 M 0 H -0.6 Reference: Stakeholder consults (GH)	distance to nearest market  L 1 M 0 H -1	distance to nearest market  L 0.6 M 0 H -0.6 Reference: Stakeholder consult (GH, BF)

	SWC	Irrigation	Small Reservoirs
D_transport Thresholds (%): BF / GH L 12-31 / 11-26 M 31-51.9 / 26-64 H 51.9-75.1 / 64-70	access to transport  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	access to transport  L -1 M 0 H 1	access to transport  L -1 M 0 H 1
D_cell_net Thresholds (%): BF / GH L 8-14.3 / 12-18 M 14.3-16 / 18-29 H 16-66 / 29-58	possess a cellphone  L -1 M 0 H 1	possess a cellphone  L -1 M 0 H 1	possess a cellphone  L -1 M 0 H 1
D_input_market Thresholds (# agro-dealers km^{-2}): BF / GH L 0.4-0.7 M 0.7-2.7 H 2.7-4.4	density of input markets  L -1 M 0 H 1	density of input markets  L -1 M 0 H 1	density of input markets  L -1 M 0 H 1
D_output_market Thresholds (# populated places 1000 km^{-2}): BF / GH L 0-0. 6 / 0-2 M 0. 6-2 / 2-5 H 2-60 / 5-340	density of output markets  L -1 M 0 H 1	density of output markets  L -1 M 0 H 1	density of output markets  L -1 M 0 H 1
Natural capital			
Soil suitability for agriculture			
D_SOC Thresholds (% district with high SOC): BF / GH L 6-69 / 86-91 M 69-100 / 91-98 H 100 / 98-100	soil organic carbon content  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	soil organic carbon content  L -1 M 0 H 1	soil organic carbon content  L -1 M 0 H 1
D_clay Thresholds (% district with high clay content): BF / GH L 0-56 / 52-55 M 56-93 / 55-65 H 93-100 / 65-100	presence of clay  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	presence of clay  L -1 M 0 H 1	presence of clay  L -1 M 0 H 1

	SWC	Irrigation	Small Reservoirs
Land availability			
D_cropland Thresholds (ha): BF GH L 0-5477 1793-24142 M 5477-10608 24142-59323 H 10608-82561 59323-331228	total cropland area  L -1 M 0 H 1	total cropland area  L -0.6 M 0 H 0.6	total cropland area  L -1 M 0 H 1 Reference: Stakeholder consults (BF)
D_pop_dens Thresholds: BF GH L 10-41.9 35-58.4 M 41.9-76.4 58.4-118.4 H 76.4-616 118.4-1236	population density  L 0.6 M 0 H -0.6 Reference: Stakeholder consults (GH)	population density  L 0.6 M 0 H -0.6 Reference:	
Biomass availability for agriculture			
D_bio_prod Thresholds: BF GH L 0-0.05 1.2-1.9 M 0.05-0.38 1.9-2.3 H 0.38-2.07 2.3-2.6	potential biomass production  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	potential biomass production  L -1 M 0 H 1 Reference: Stakeholder consults (GH)	potential biomass production  L -1 M 0 H 1
Reduced risk			
D_MARcv Thresholds: BF GH L 0.08-0.099 0.05-0.06 M 0.099-0.1 0.06-0.076 H 0.1-0.13 0.76-0.095	likelihood of dryspells during growing season  L 1 M 0 H -1	likelihood of dryspells during growing season  L 1 M 0 H -1	likelihood of dryspells during growing season  L -1 M 0 H 1

Volta : Factor – Capital

How important is a high level of the *factor* (e.g. Water availability for agriculture) to achieving a high level of the *capital* (e.g. Water resources)? Where:

4 = Essential; 3 = Very important; 2 = Important; 1 = Somewhat important; 0 = Not important

	Soil Water Conservation**	Small scale irrigation	Small reservoirs
Water availability	4	4	4
Water access	4	4	4
Water quality	0	3	2
Organisational capacity	3	3	3
Support network	3	3*	3*
Land access	3	2	2
Conflict	3	3	2
Gender	3	2	2
Wealth	3*	3*	3*
Credit access	3	3	3
Health	3	1	4
Labour availability	4	3	3
Skills	4	2	2
Infrastructure	4	3	3
Market access	3	4	4
Soil suitability	4	1	3
Land availability	4	4	4
Biomass	4	1	2
Extreme Weather*	3*	-	3*
Weeds and pests	2	3	3

* No weight given by workshop participants, so value assigned by modeller
** same as Limpopo - no input from workshop participants

Volta : Capital – Success

How necessary is the *capital* (e.g. Water resources) for successful projects? Where:

4 = Essential (the project will certainly fail without it); 3 = Important; 2 = Somewhat Important; 1= Not important (its presence or absence will make no difference to the likelihood of success)

	Soil Water Conservation**	Small scale irrigation	Small reservoirs
Water resources	4	4	4
Social capital	3	3	3
Financial capital	3	3	3
Human capital	3	3	3
Physical capital	3	4	4
Natural capital	4	3	3
** same as Limpopo - no input from workshop participants			

Volta : Data missing

* denotes data is missing

	Burkina Faso	Ghana
Water resources		
Water availability for agriculture		
mean annual rainfall (mm)		
Water accessibility for agriculture		
% district area <1km to a river		
depth of water table		
access to surface water		
access to water infrastructure	*	*
Water quality for agriculture		
salinity of water	*	*
Social Capital		
Community leadership & Organisational capacity		
number of community organisations		
voting turnout (%)		
number of conflicting interest groups	*	*
number of disputes managed	*	*
Support network available		
access to information from radio, newspaper or TV		
proportion of income from remittances	*	
No Conflict		
number of ethnic groups	*	*
unemployment rate		*
Access to land		
ownership of land		

	Burkina Faso	Ghana
Gendered access to resources		
proportion of female-headed households		
women with credit	*	
Financial capital		
Wealth		
incidence of poverty		
Access to credit		
availability of micro-finance institutions		
Human capital		
Health status		
households with safe drinking water		
malnutrition prevalence		
density of clinics		
Labour availability		
working age population (15-65)		
gender ratio (women:men)		
migration	*	*
income generation	*	*
Skills (education and training)		
literacy rate		
agricultural extension services	*	*
Physical capital		
Physical infrastructure		
proximity to a road		
access to agricultural equipment		
Access to markets		
distance to the nearest market town		
possession of cellphones		
density of input markets	*	
density of output markets		
have transportation		
Natural capital		
Soil suitability for agriculture		
soil organic carbon content		
presence of clay loam in the district		
Land availability for agriculture		
total cropland area		
average slope	*	*
population density		
urbanisation	*	*
Biomass availability for agriculture		

	Burkina Faso	Ghana
potential biomass production		
Weather variability		
incidence of dry spells during growing season		
Agricultural pests and diseases		
loss of harvest to pests or disease	*	*