CIS Based DST — Software for Socioeconomic Benefit

Initiatives in Crop Capability Prediction Modelling as Part Of Decision Support System for Agriculture and Food Security in Sub-Saharan Africa

Institutional Linkages, South-South Partnerships and Capacity Building Hands-on Workshops on Objective Climate Forecasts for Agriculture and Food Security Sector in Eastern and Southern Africa Training Workshop

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Sub-Saharan Africa agricultural productivity

- In Sub-Saharan Africa (SSA), agriculture plays a key role in both food security and employment areas. Agriculture contributes to:
  - typically between 25 and 40% of GDP; and
  - up to 60% of employment.
- However, Productivity is only about 1MT/Ha compared to 5-10 MT/Ha in other parts of the globe.
  - low productivity=> very the high cost of production, making it largely sub-economic;
  - (but) this may be the difference between starving and food secure.
- There is a great potential of increasing the productivity, particularly as the agricultural sectors utilize CIS in supporting on farm strategic and tactical decisions.

Climate effects on agricultural productivity

Variability of climate & weather in form of drought/floods controls many facets of agricultural production systems.

- It affects 70% of the production costs.
- There is beneficial use of seasonal climate forecasts (SCF) in the prediction of crop yields for economic growth and food security.
- Provision of actionable advisories on monitoring and prediction of performances of these parameters can go a long way in sustainable and climate smart agriculture.
- However, in most SSA countries there are perennial challenges of data gaps which affects improvements of SCF and crop yield projections.
- These data gaps may be addressed through use of Artificial Intelligence (AI) and Machine Learning.

Impacts of Climate Extremes on Agriculture/Food Security

Population in drought prone regions

Likelihood of Production losses due drought

Productivity losses due to drought

Negative impacts on Food Security for the Population

Population in flood prone regions

Likelihood of Production losses due floods

Productivity losses due to flood

Example of cases of perennial food insecurity in SSA

In 2016 Southern African Development Community (SADC) Regional Food Security and Vulnerability Assessments indicated that due to the El- Niño-induced drought, the number of food insecure people in the region is about 40 million, which is about 14% of SADC's total population". This led to:-

- The SADC declared a Regional Disaster and launched an Appeal amounting to US $2.4 billion to support the humanitarian needs, mostly food, and disaster response recovery of millions of people affected by in the region.

(Continued……)

CIS Based DST

Software for Socioeconomic Benefit

SSA Food Insecurity

- It is important to note that in August 2015 SADC CSC together with SADC NMHSs issued the drought affecting the region in August 2015.

- Meantime, up to September 2015 grain was priced at about US$ 250 per ton. However, the price jumped to nearly US$500 per ton after October 2015, (FAO/FEWSNET reports).

- SADC could have saved up to US$ 200 per every ton imported.
- So if the SADC Region required to import 2 0000 000 tons, this would cost US$ 1 Billion.

- This is double the US$500 million it would have cost if the importation was done timely on
- the basis timely use of SARCOF statement issued in August 2015.
- Estimated 700000 heads of cattle were lost due to the drought, (SADC, 2016).
- The millions of dollars lost as herd of cattle was decimated by drought could have been avoided if there was timely application of CIS on the basis of SARCOF.

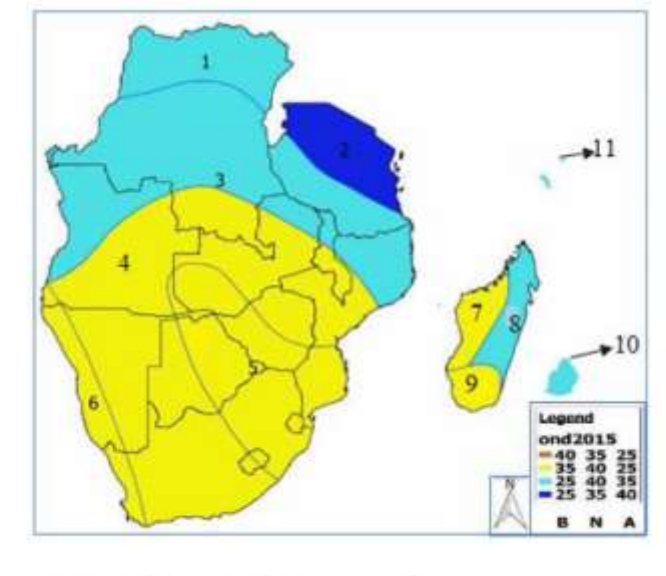


Fig 1: Rainfall forecast for Oct-December 2015

NOVEMBER-DECEMBER 2015-JANUARY 2016

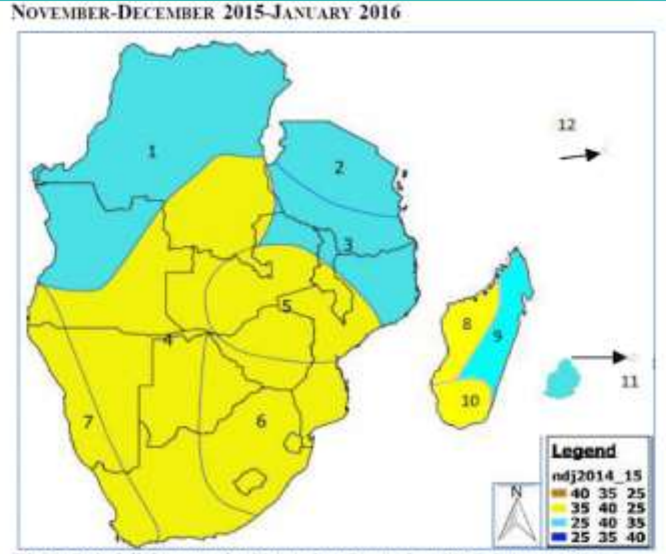
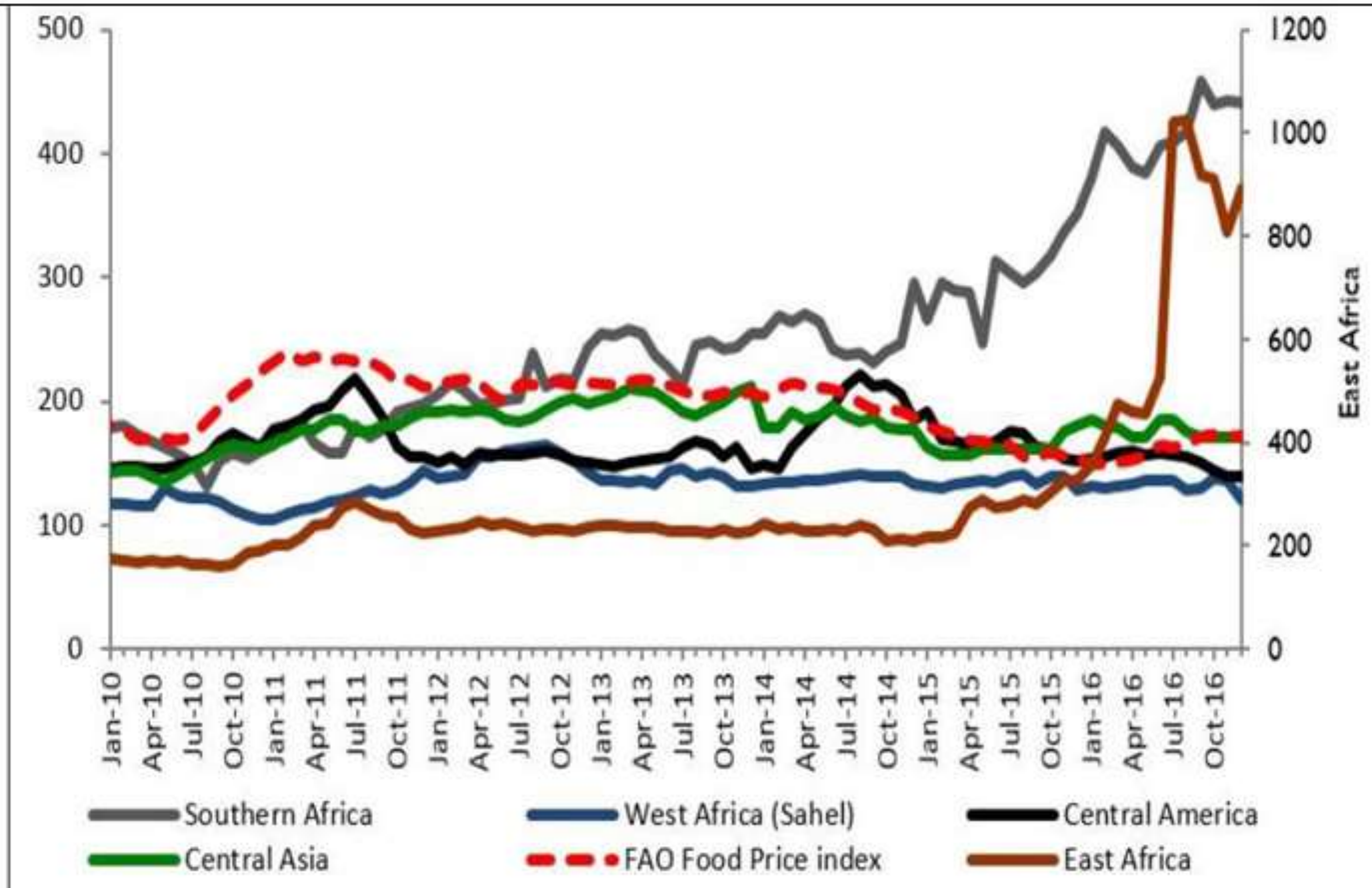


Fig 2: Rainfall forecast for November-December 2015-January 2016

SSA food insecurity

…….Some missed opportunities

Figure 14.2 FEWSNET regional price indices and FAO Food Price Index, Jan 2010-Dec2016



Source: FAO and FEWS NET.

Seasonal Climate Forecast Reliability

Using contingency table to establish reliability of SCF

		Observed		
		Yes	No	
Forecast	Yes	a	b	a + b
	No	c	d	c + d
		a + c	b + d	n = a + b + c + d

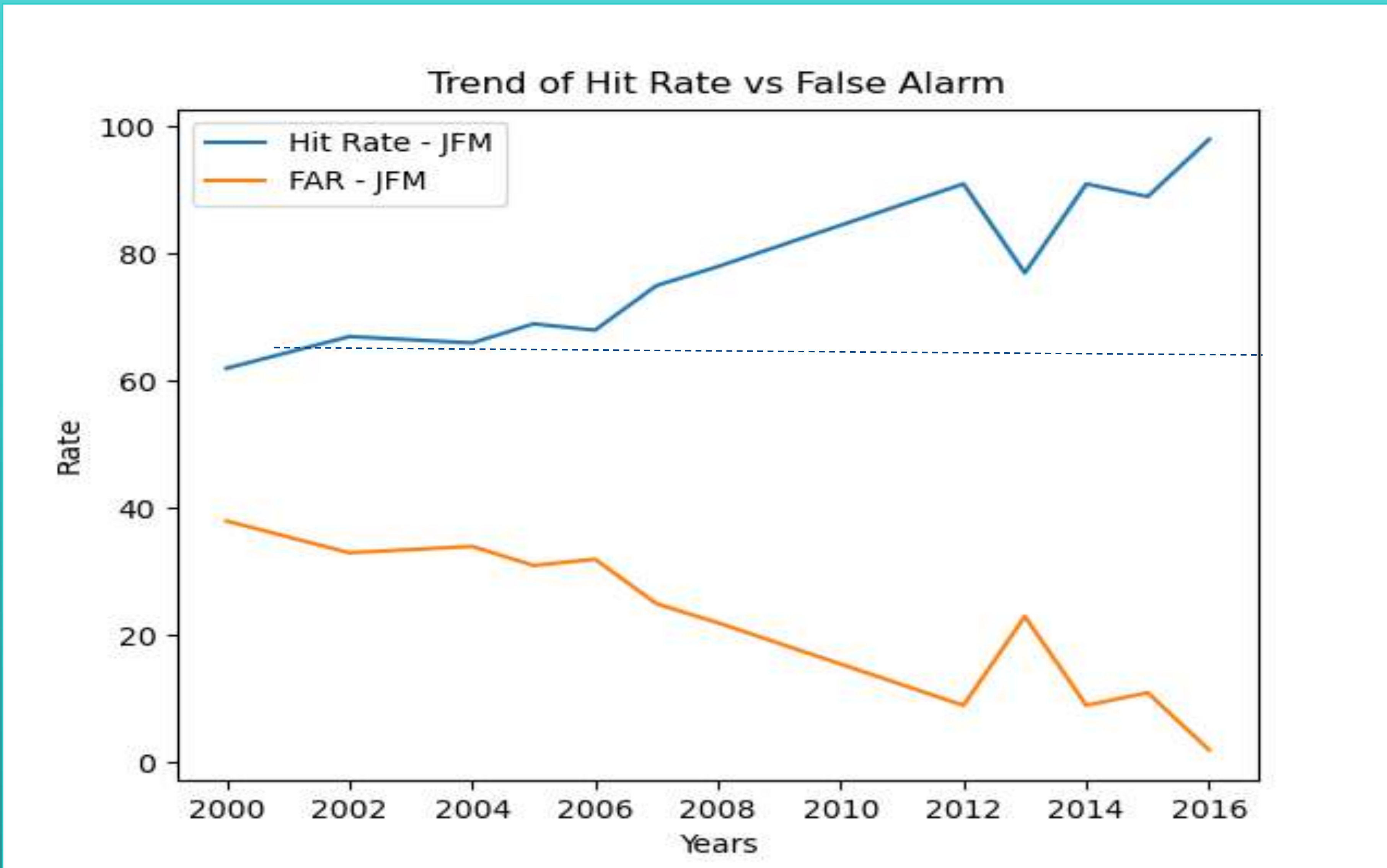
Contingency Table

Above table looks at four possible outcomes:

- An event is forecast and the event occurs (a)
- An event is forecast and the event does not occur (b)
- An event is not forecast and the event occurs (c)
- An event is not forecast and the event does not occur (d)

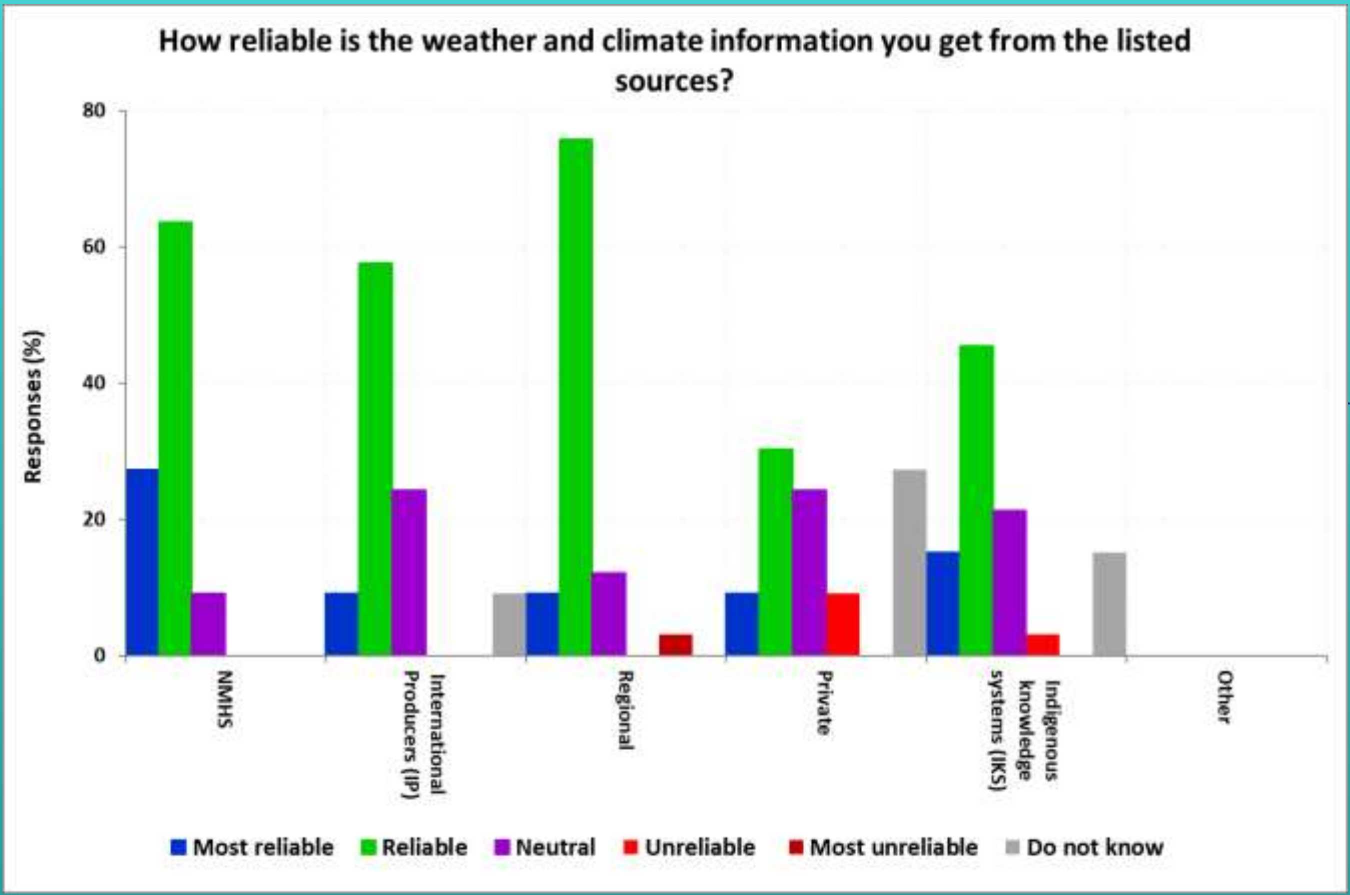
Hit Rate: ***H = a/(a + c)*** ***False Alarm Rate: FAR = b/(a + b)***

Seasonal Forecast Reliability



SADC HIT RATE VS FALSE ALARM 2000 – 2016 SEASON JFM

Seasonal Forecast Reliability: Perception of User-Community

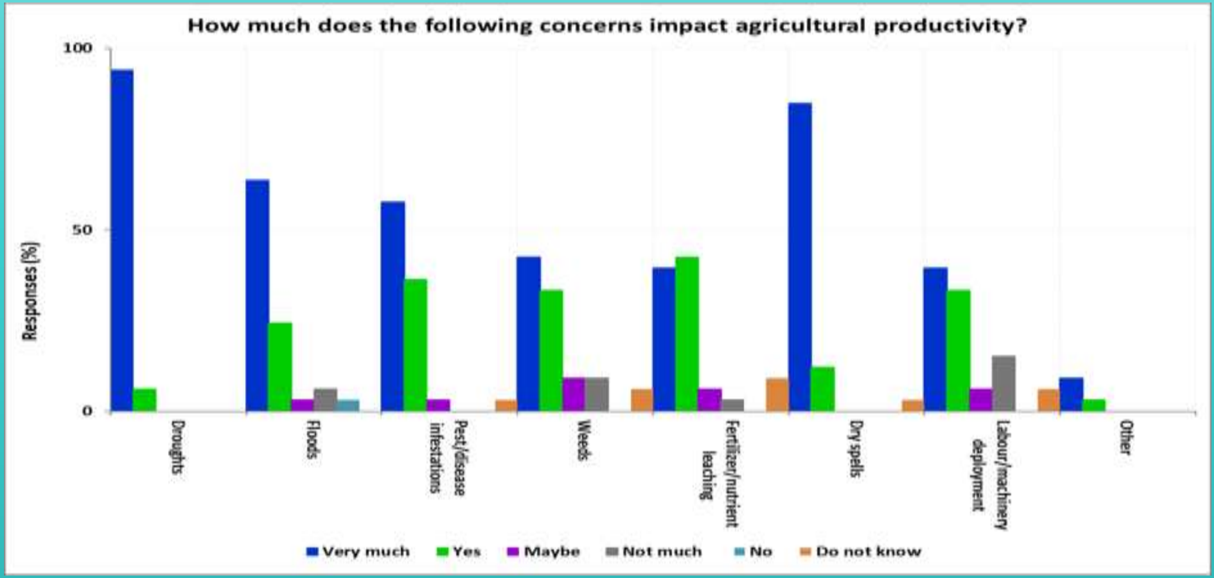


- NMHSs were rated most reliable by more of the respondents followed by IKS.
- In the second rank, i.e. reliable box, regional sources topped the list. This was followed by local NMHSs and international sources.

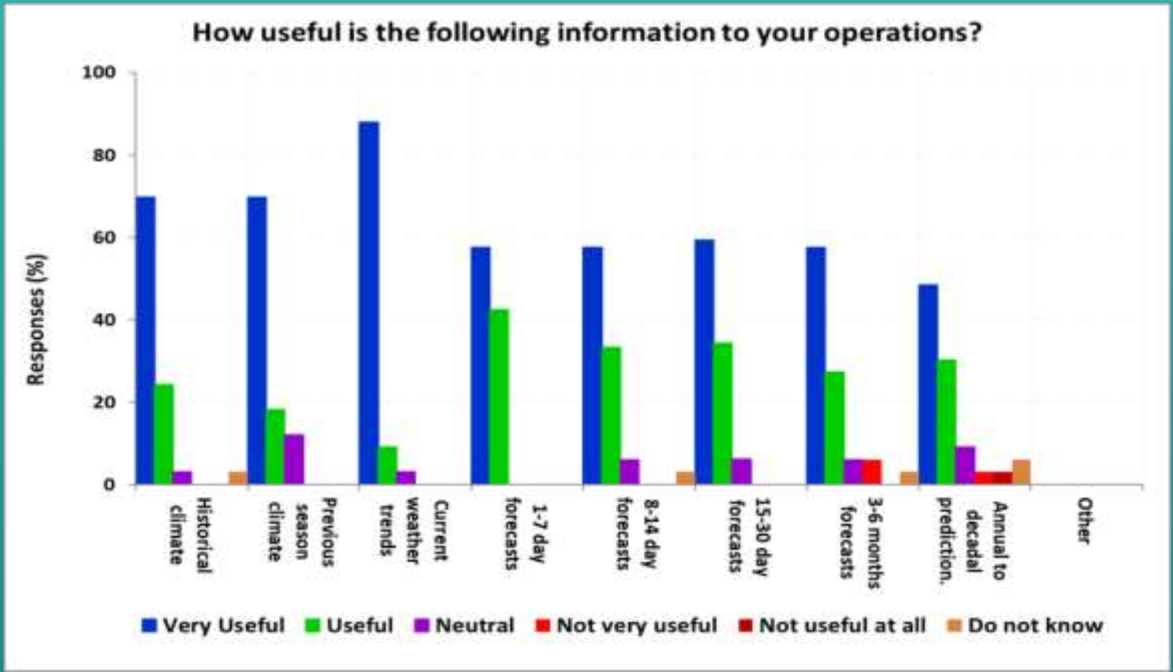
User needs

- Users overwhelmingly attributed negative impacts of agricultural production to droughts, dry spells and floods.
- Then labour and plant equipment hire. Weeds, nutrients were attributed to negatively impact production by 45% of the responders.
- The farmers appeared quite knowledgeable of the climate induced success or failure factors to production

Climate impacts on Agriculture Productivity



Usability of weather and climate products in Agricultural Sector

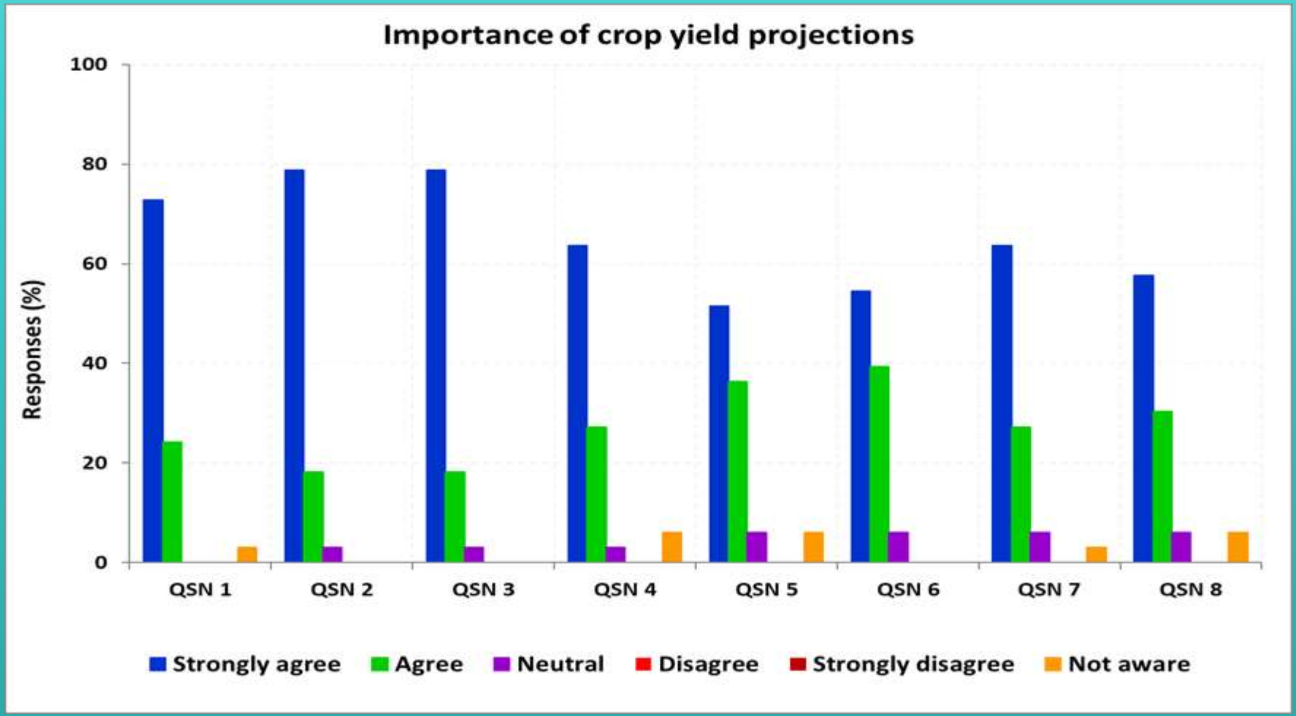


- Current weather seemed to top the list as being very useful followed by historical climate and previous season climate.
- These all came ahead of a 3-6 six months forecast which should be a major planning tool in agriculture.
- Its importance appears tied with 1-7 day, 8-14 day and 14-30 day forecasts. This may have to do with perception of reliability of current seasonal climate forecast (SCF) to the user community

User needs

- There were strongly agreed on the importance of this in the sector.
- Stakeholders noted that crop capability prediction is an important tool in planning for GDP projection, food security assessment, importation and export of food should there be surplus of deficits projections.

Importance of crop yield projections on agriculture productivity



QSN1- Advance knowledge of crop yield projection is important
QSN2- It is important for planning
QSN3- It is important for food security
QSN4- It is important for GDP projections
QSN5- It is important for investment planning
QSN6- It is important for relief efforts
QSN7- It is important for grain marketing including import and export
QSN8- It is important for health/nutritional planning

Producer capacity

The capacity of NMHSs to generate optimal quality and range of products and services for application by the user-community was assessed. The responses of NMHSs generally showed that currently they have:

- insufficient tailor made climate information for sectors
- inadequate technical competencies for the production, tailoring and communication of climate services at the national level.
- inadequacy of the suite of products generated (climate monitoring products, medium-range forecast; seasonal /interannual/decadal predictions, projections, etc.) to satisfy user needs, especially in Agriculture/Food Security Sector.

The NMHSs noted that there are climate information products/services being generated for national-level users currently especially in the agriculture/food security sector

Focus Areas:

- Development of Decision Support System for Agriculture based on Climate Information Services (CIS);
- Actionable CIS-based tools for climate-sensitive sectors, e.g.:
  - Crop yield projection models; and
  - Forecast Based Action for DRR

Why addressing this challenge is important

Taking into account the foregoing it is clear that there is need for capacitating the producers and users of CIS in order to develop robust CIS-Based DSS for Agriculture and Food Security.

Such CIS-Based DSS can guide decisions of communities for optimum productivity and mitigation of negative impacts of hydrometeorological hazards. This is achieved through:

- **improved efficiencies in agricultural production systems; and**
- **improved food security by cost-effective imports/exports.**

This will enhance contribution of climate-sensitive sectors to sustainable economic growth;

(Continued….)

Why addressing this challenge is important

- There is proven over **5-10 times return on investment** in developing optimal CIS, but **policy- and decision-making is not aware** of such **benefit-cost ratios (UNECA; 2020)**; and
- CIS enables society to better adapt to seasonal shifts of rainfall due to Climate Change

Data and Methodological Approach

Multi-step approach which involves:

- Interpreting Agroecological Zones;
- Developing Homogeneous Rainfall Zones;
- Data collection for:
  - Climatic parameters (SRAD, TMAX.TMN, RAIN)
  - Crop cultivars; and
  - Soil types.
- Carrying out Data analytics;
- Developing and Testing Modelling Tools for:
  - Generating Seasonal Climate Forecasts (SCF) for Rainfall Zones;
  - Crop Capability Prediction per Representative Location;
- Crop Yield Models using SCF;
- Developing Actionable CIS-Based DSS such as:
  - Crop Yield Exceedance Probabilities;
  - Developing Forecast Based Action;
  - Generate accompanying bulletin;
- Disseminating Bulletins; and
- Capacity development.

Seasonal Climate Forecasts For Crop Yield Modelling

Crop growth simulation models are a synthesis of detailed knowledge on plant physiological processes in order to explain the functioning of crops as a whole, Choudhary (2018). These can be used with Seasonal Climate Forecast (SCF) in Crop Yield Prediction Models.

- Crop growth is more complex and occurs continuously in time, thus requiring at least daily inputs of weather parameters, while the SCFs are currently only possible in three monthly blocks.

- Weather generators e.g. Climate –Agriculture Modelling Decision Tool (CAMDT) are used to reconfigure SCF into daily weather realizations as input into crop growth simulation models for yield prediction.

- Crop growth simulation models e.g. Decision Support System For Agro-technology Transfer (DSSAT), used in combination with seasonal climate forecasts as input for the purposes of generating crop yield projections with long lead times, typically three months in advance.
- CAMDT is used to drive DSSAT Rice Model. Other different weather generators and crop simulation models can also be used in crop yield prediction modelling.

Overview Of Crop Simulation Models

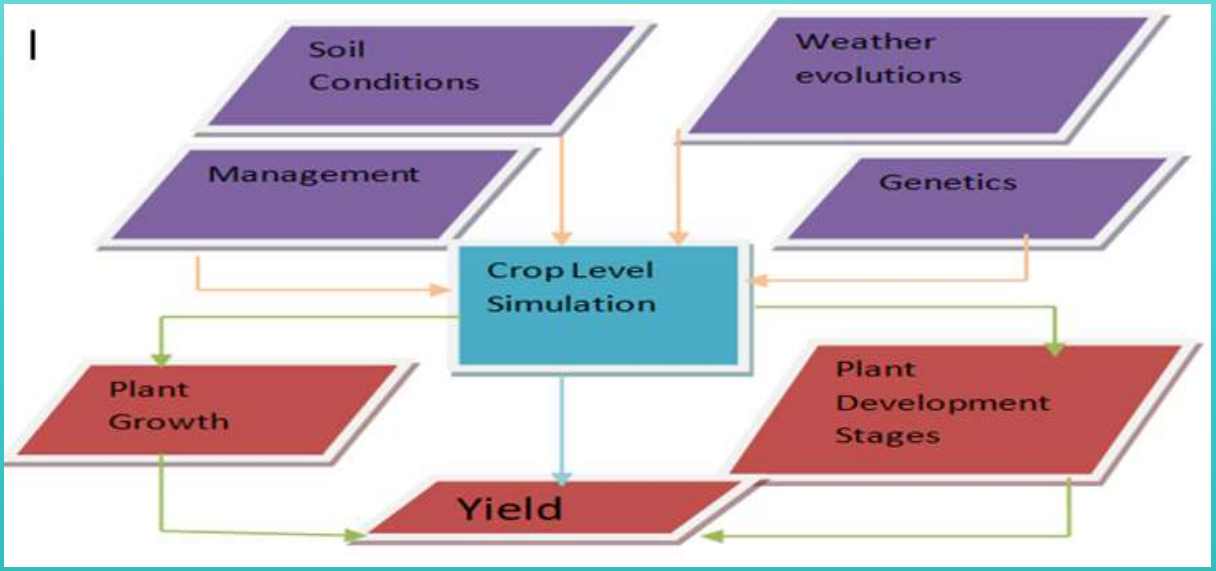
For better understanding of crop development, simulation models are used. A simulation model is a schematic representation of the conception of a system or a set of equations, which represents the behaviour of a system. There are many types of models:

- **Statistical models**: These models express the relationship between yield or yield components and weather parameters using statistical techniques.
- **Mechanistic models**: These models explain the mechanism of these models.
- **Deterministic models**: These models estimate the exact value of the yield or dependent variable.
- **Stochastic models**: For each set of inputs different outputs are given along with probabilities.
- **Simulation models**: are mathematical representation of a real world system. These models use one or more sets of differential equations, and calculate both rate and state variables over time, normally from planting until harvest maturity or final harvest.
-

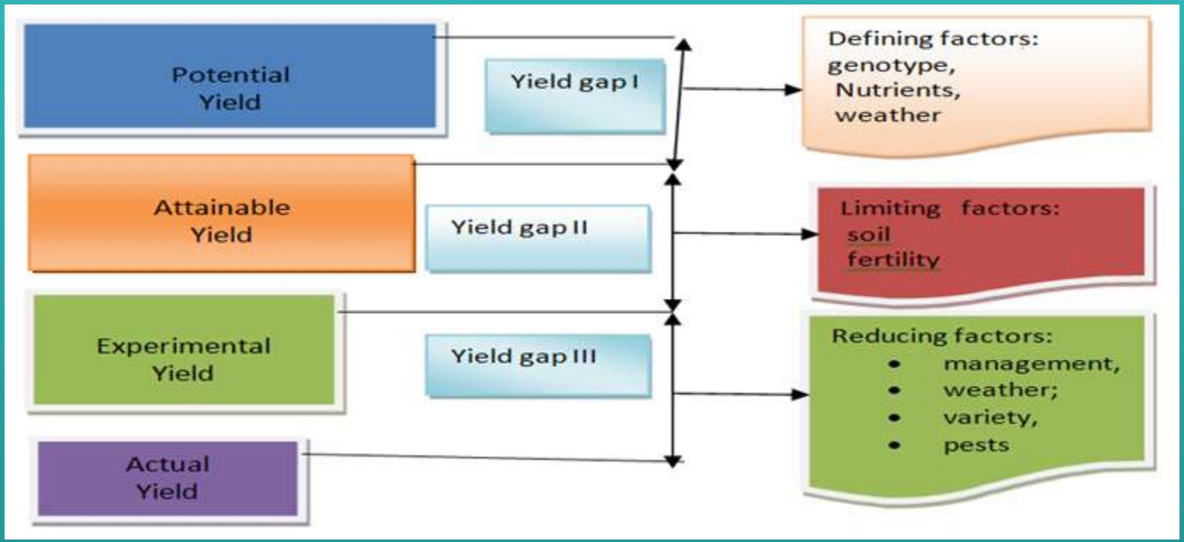
DSSAT

Decision Support System for Agro-Technology Transfer (DSSAT), developed by J.W. Jones, in the USA and his co-workers. The DSSAT package consists of crop growth and yield models built on a framework similar in structure.

The package consists of:
1) Database management system for soil, weather, genetic coefficients, and management inputs,
2) Crop simulation models,
3) Series of utility programmes,
4) Series of weather generation programmes,
5) Strategy evaluation programme to evaluate options including choice of variety, planting date, plant population density, row spacing, soil type, irrigation, fertilizer application, initial conditions on yields, and water stress in the vegetative or reproductive stages of development, and net returns.



Schematic of crop yield model



Schematic of yield gap

Weather Generators

- Crop genotypic phenologies vary continuously in time so, therefore, need daily assessment.
- For long time-leads, the skills for usable accuracies of climate forecasts are on seasonal timescales, typically three monthly.

- There is a need to find ways of marrying seasonal climate forecasts (SCFs) with crop simulation models in order to develop crop capability prediction models.
- There is a need to use techniques such as downscaling the three-monthly seasonal climate forecasts both spatially and temporally in order for driving crop growth simulation models to provide crop capability forecasts.

- One of the techniques employed in downscaling SCF is through the use of weather generators.

- This is a stochastic process whereby the behaviour of daily historical climate data are assessed and simulated on daily timescales. This leads to SCF being more conveniently packaged to drive the crop yield models, (Hansen et al, 2006).

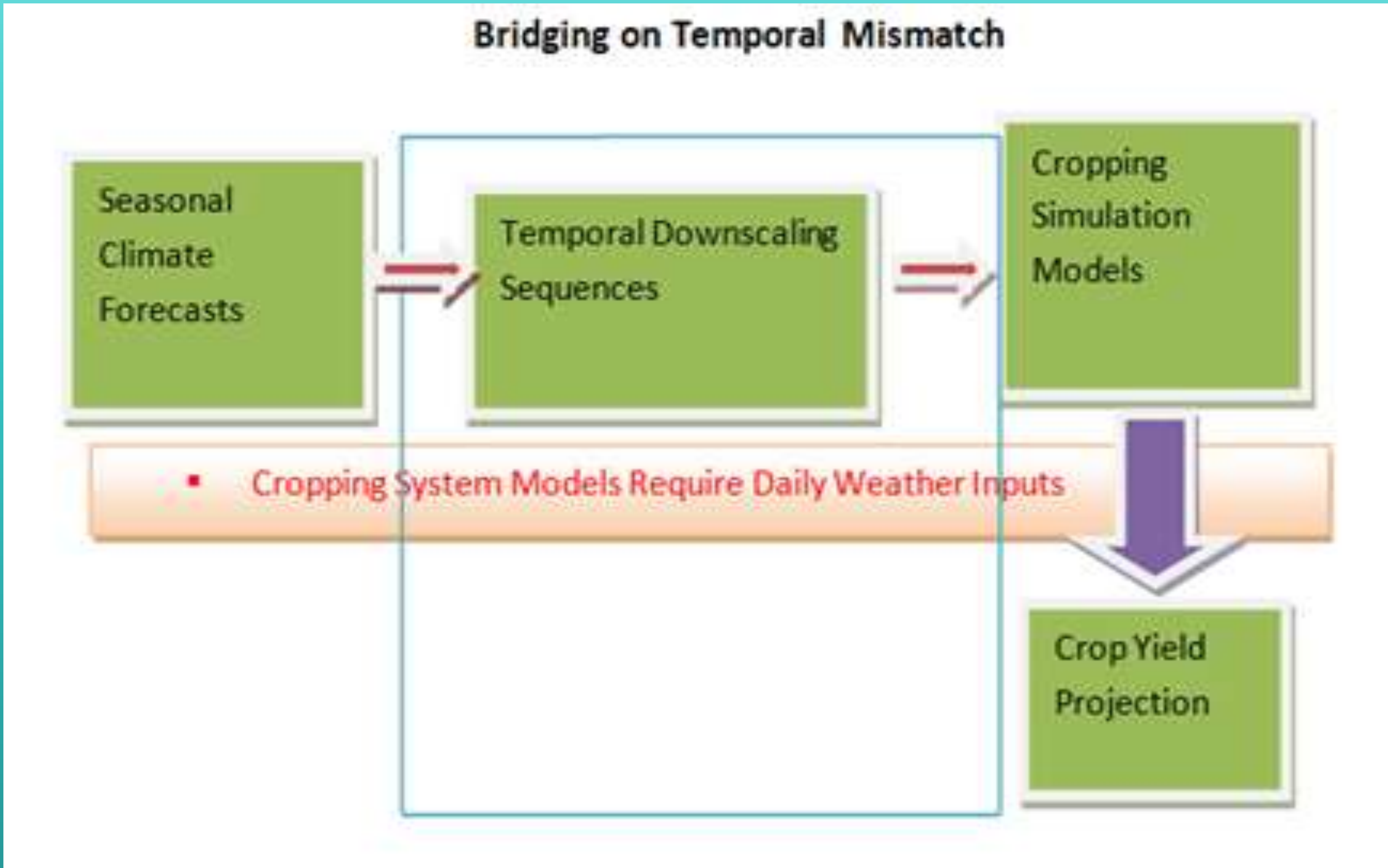
Combination of CAMDT-DSAT Models

The CAMDT tool enables the stakeholders to have an overview of the feasibility of a desired Prediction horizon (farming season) for particular homogeneous rainfall zones.

CAMDT uses the *prediction horizon that* can be set for Nov-Jan (NDJ) Dec-Jan-Feb, (DJF) or Jan-Feb- Mar (JFM) or Feb-Mar-Apr (FMA).

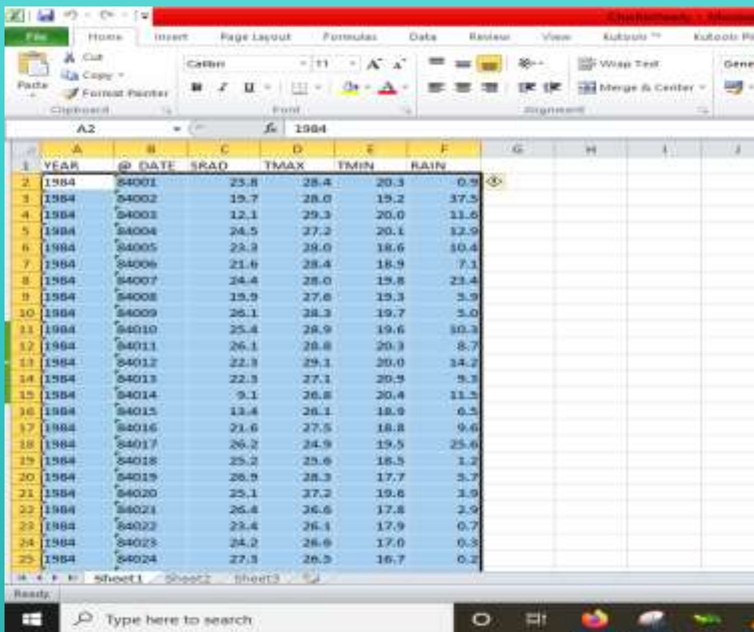
Temporal downscaling

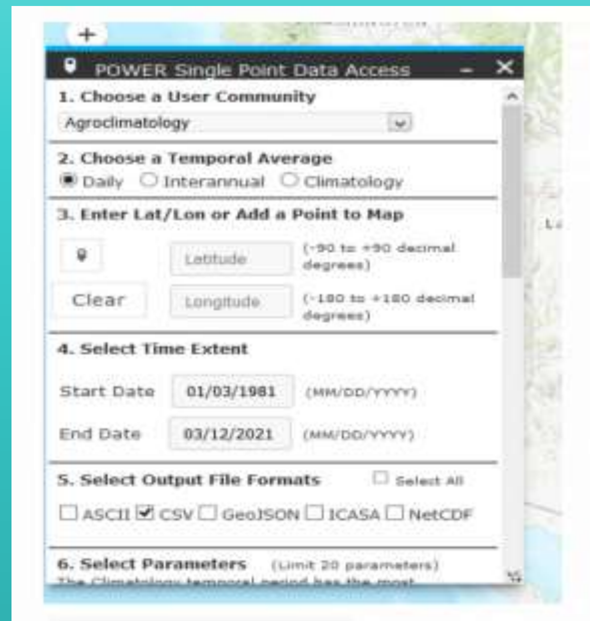
Most of the publicly accessible seasonal climate forecasts (SCF) are released in the format of tercile probability: below-, near- and above-normal probability.
The tercile-based SCF should be converted to daily weather sequences to force the DSSAT simulations. This is a temporal downscaling process.

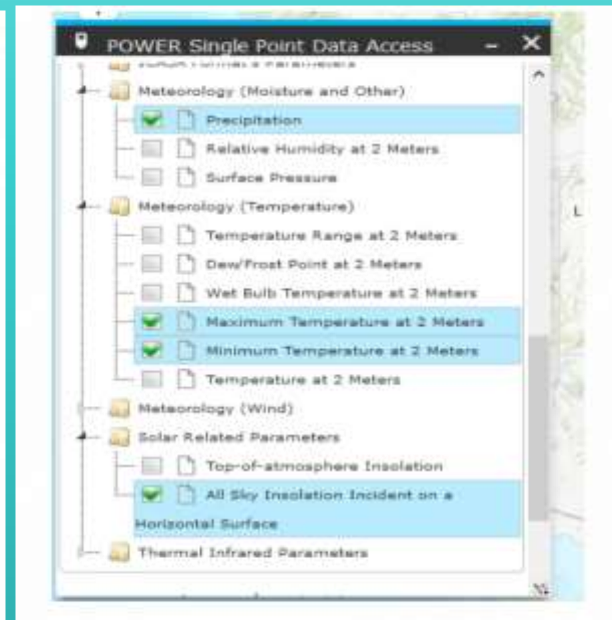


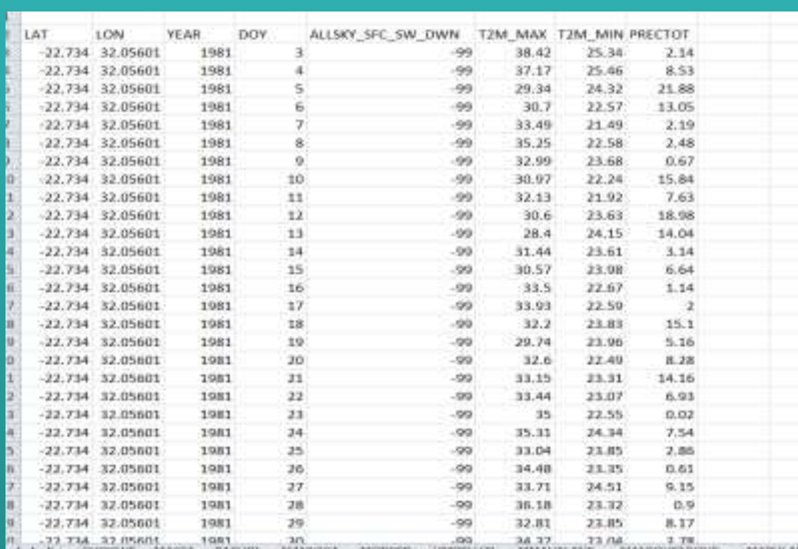
SCHEMATIC OF TEMPORAL DOWNSCALING OF SCF AS INPUT INTO CROP YIELD MODELS

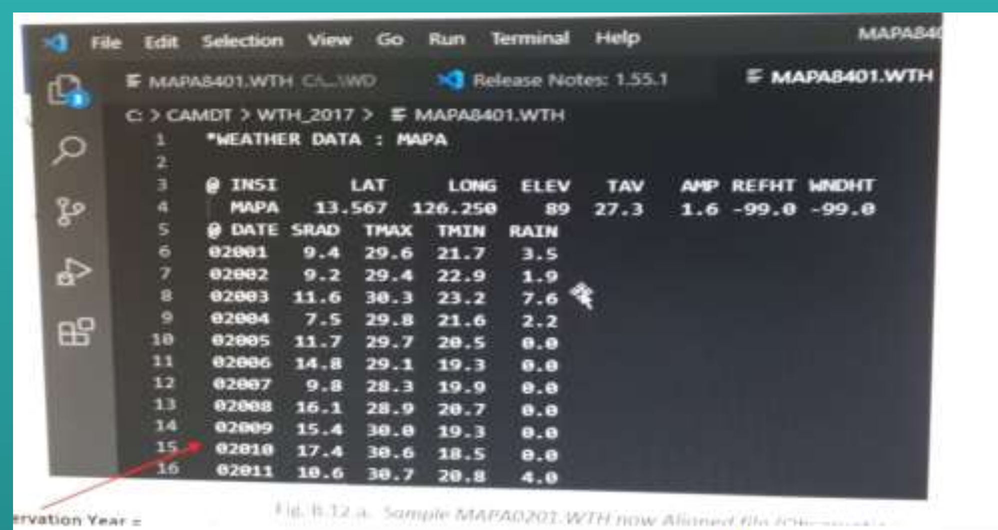
Data Analytics







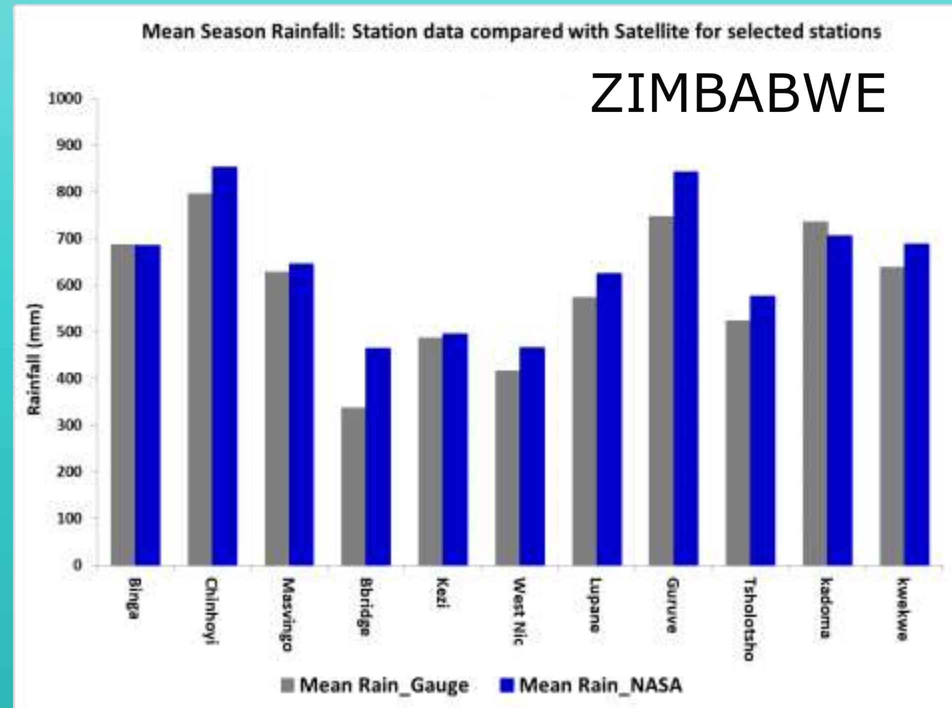


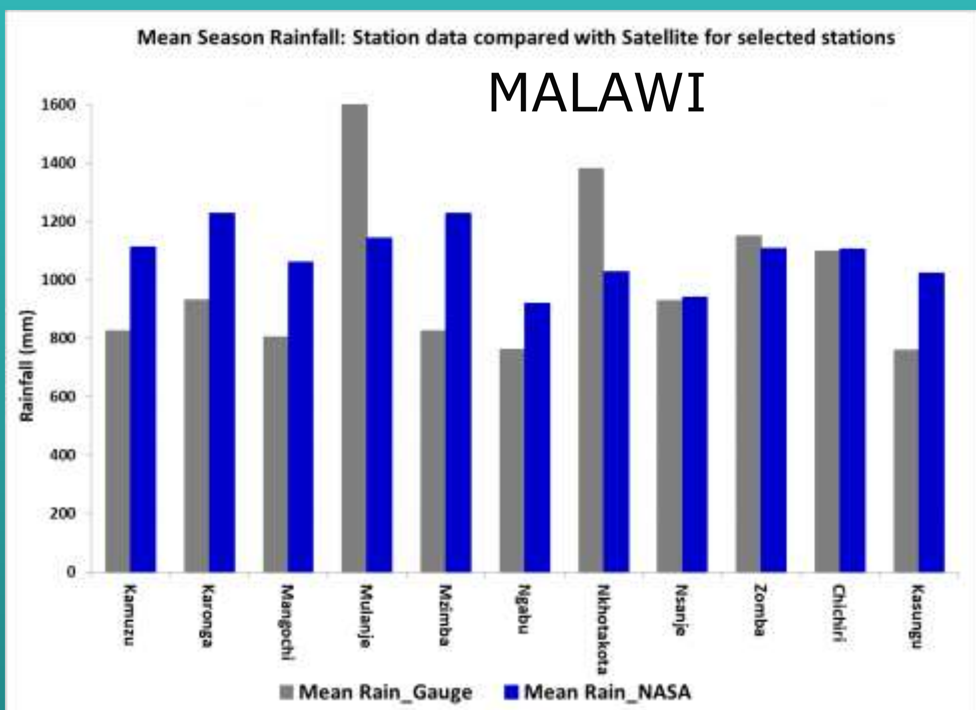


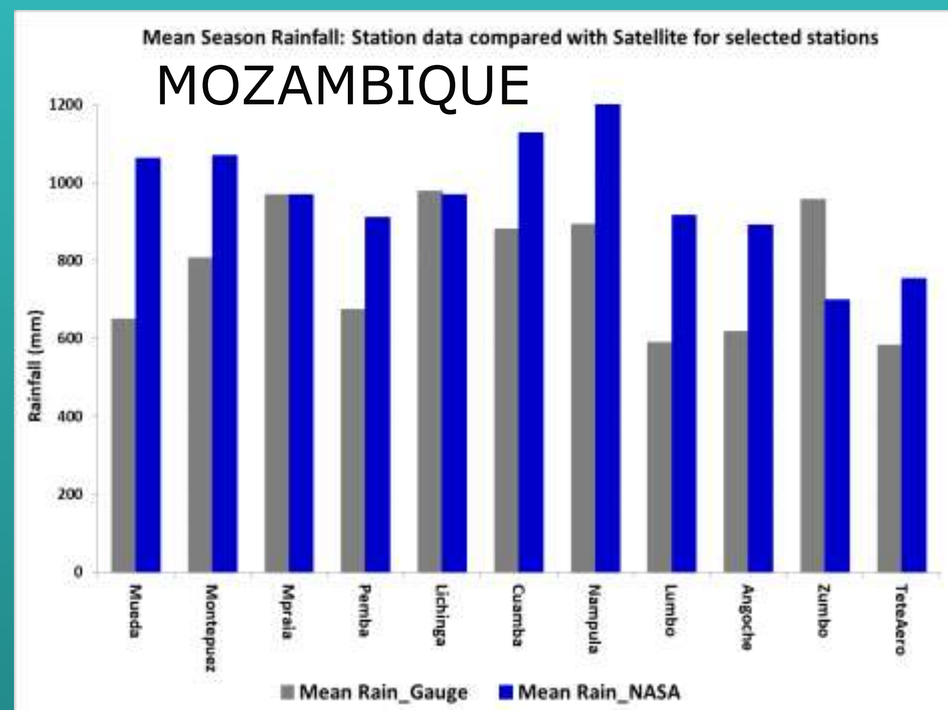
Data Analytics

SAMPLE OF NASA vrs NATIONAL DATA

- NASA data in general overestimates the rainfall at a station in all three countries







Crop Cultivar Coefficients

Rice

The rice cultivar index number RICE046 was used in the trial runs. This cultivar has the coefficients as follows:

- P1 Time period (expressed as growing degree days [GDD] in øC above
- a base temperature of 9øC) from seedling emergence during which
- the rice plant is not responsive to changes in photoperiod. This
- period is also referred to as the basic vegetative phase of the plant.
- P2O Critical photoperiod or the longest day length (in hours) at
- which the development occurs at a maximum rate. At values higher
- than P2O developmental rate is slowed, hence there is delay due
- to longer day lengths.
- P2R Extent to which phasic development leading to panicle initiation
- is delayed (expressed as GDD in øC) for each hour increase in
- photoperiod above P2O.
- P5 Time period in GDD øC) from beginning of grain filling (3 to
- 4 days after flowering) to physiological maturity with a base
- temperature of 9øC.

(Continued….)

Rice

- G1 Potential spikelet number coefficient as estimated from the
- number of spikelets per g of main culm dry weight (less lead
- blades and sheaths plus spikes) at anthesis. A typical value is 55.
- G2 Single grain weight (g) under ideal growing conditions, i.e.
- non limiting light, water, nutrients, and absence of pests
- and diseases.
- G3 Tillering coefficient (scaler value) relative to IR64 cultivar
- under ideal conditions. A higher tillering cultivar would have
- coefficient greater than 1.0.
- G4 Temperature tolerance coefficient. Usually 1.0 for varieties
- grown in normal environments. G4 for japonica type rice growing
- in a warmer environment would be 1.0 or greater. Likewise, the
- G4 value for indica type rice in very cool environments or
- season would be less than 1.0.

Crop Cultivar Coefficients

Maize

The maize cultivar index number MZCER046 was used in the trial runs. This cultivar has the coefficients as follows:

- P1 Thermal time from seedling emergence to the end of the juvenile
- phase (in degree days above a base temperature of 8 deg.C)
- during which the plant is not responsive to changes in photoperiod.
- P2 Extent to which development (expressed as days) is delayed for
- each hour increase in photoperiod above the longest photoperiod
- at which development proceeds at a maximum rate (which is
- considered to be 12.5 hours).
- P5 Thermal time from silking to physiological maturity (expressed
- in degree days above a base temperature of 8 deg.C).
- G2 Maximum possible number of kernels per plant.
- G3 Kernel filling rate during the linear grain filling stage and
- under optimum conditions (mg/day).
- PHINT Phylochron interval; the interval in thermal time (degree days)
- between successive leaf tip appearances.

Crop Cultivar Coefficients

Sorghum Cultivar Index Number SGCER046 Coefficients

- The sorghum cultivar index number SGCER046 was used in the trial runs. This cultivar has the coefficients as follows:
- P1 Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above TBASE during which the plant is not responsive to changes in photoperiod.
- P2 Thermal time from the end of the juvenile stage to tassel initiation under short days (degree days above TBASE).
- P2O Critical photoperiod or the longest day length (in hours) at which development occurs at a maximum rate. At values higher than P2O, the rate of development is reduced.
- P2R Extent to which phasic development leading to panicle initiation (expressed in degree days) is delayed for each hour increase in photoperiod above P2O
- PANTH Thermal time from the end of tassel initiation to anthesis (degree days above TBASE).
- P3 Thermal time from to end of flag leaf expansion to anthesis (degree days
- above TBASE).
- P4 Thermal time from anthesis to beginning grain filling (degree days above TBASE).
- P5 Thermal time from beginning of grain filling to physiological maturity (degree days above TBASE)

(Continued………)

Sorghum

- PHINT Phylochron interval; the interval in thermal time between successive leaf tip appearances (degree days).
- G1 Scaler for relative leaf size.
- G2 Scaler for partitioning of assimilates to the panicle (head).
- PSAT Critical photoperiod below which development is not delayed (optional).
- PBASE Ceiling photoperiod above which development is delayed indefinitely (optional).

Sample soil profile

WI.SOL - Notepad

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!
! CLAY, SILT CLAY, SILT CLAY LOAM, SANDY ALGORTA AND SANDY RIVERA
! ***************************************************************************
!****************************************************************************
!
*WI_ANPH007  WISE        SCL      90 WISE DATABASE, SOIL PH007
@SITE        COUNTRY          LAT     LONG SCS Family
 -99         Philippines   13.433  123.400 Mollic Andosol (ANm)
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BK  0.09  9.84  0.60 75.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    15   A11 0.149 0.337 0.523  1.00  1.24  1.12  4.20 23.00 23.00 -99.0  0.26  6.40  5.50 27.70 -99.0
    30   A12 0.172 0.350 0.532  0.64  1.12  1.12  2.70 27.00 29.00 -99.0  0.15  6.40  5.30 25.80 -99.0
    50   A13 0.180 0.357 0.523  0.45  0.91  1.16  1.80 27.00 28.00 -99.0  0.12  6.40  5.70 22.90 -99.0
    70 IIB11 0.136 0.311 0.519  0.30  1.77  1.18  1.30 27.00 25.00 -99.0  0.10  6.60  5.20 21.50 -99.0
    85 IIB12 0.048 0.145 0.382  0.21 10.60  1.55  0.40 10.00 12.00 -99.0  0.04  6.70  5.90 12.00 -99.0
    90  IIIC 0.018 0.085 0.363  0.17 40.49  1.61  0.20  3.00  9.00 -99.0  0.02  6.70  5.30  8.10 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    15 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  77.0 -99.0 -99.0   2.4   5.7   0.3 -99.0 -99.0  13.0
    30 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  79.0 -99.0 -99.0   1.8   5.9   0.4 -99.0 -99.0  12.3
    50 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  82.0 -99.0 -99.0   2.2   4.8   0.6 -99.0 -99.0  11.2
    70 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  83.0 -99.0 -99.0   1.9   5.4   0.8 -99.0 -99.0   9.8
    85 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  74.0 -99.0 -99.0   1.0   1.8   0.4 -99.0 -99.0   5.7
    90 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  83.0 -99.0 -99.0   0.8   1.5   0.3 -99.0 -99.0   4.1
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Results

The SCF were provided in probabilistic rainfall terciles, i.e. Above-normal (AN); Near-Normal (NN); and Below-normal (BN).

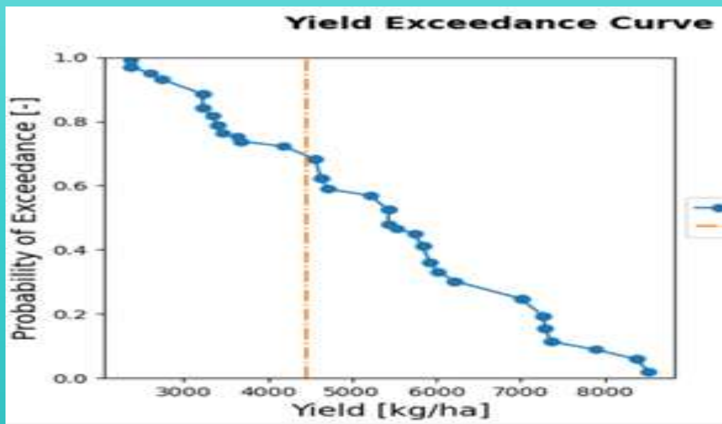
The thresholds were set to: a) 45% AN and 20% BN for above-normal rainfall case; and b) 20% AN and 45% BN for below-normal rainfall case.

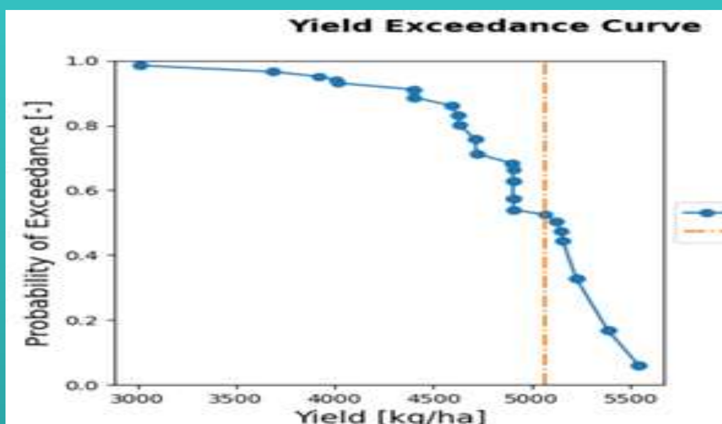
Three cultivars of Rice, Maize and Sorghum were used in the crop yield modelling exercises.

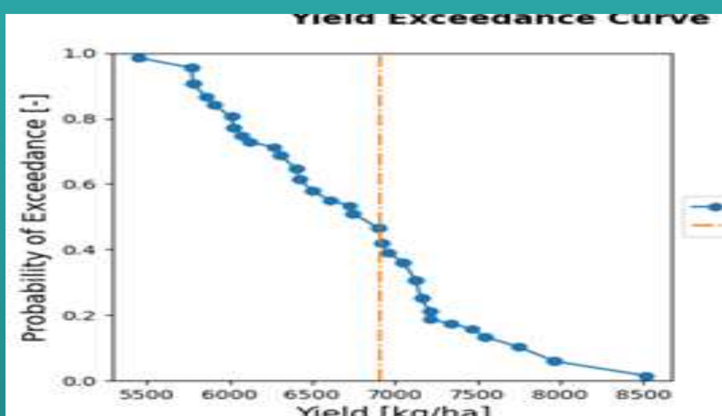
Results of four Stations are shown: Mzimba, Malawi; Tutume, Botswana; BeitBridge, Zimbabwe; and Mapai, Mozambique. These are shown as respective:

- **Yield Exceedance Probability Curves**

Yield Exceedance Probability: MZIMBA

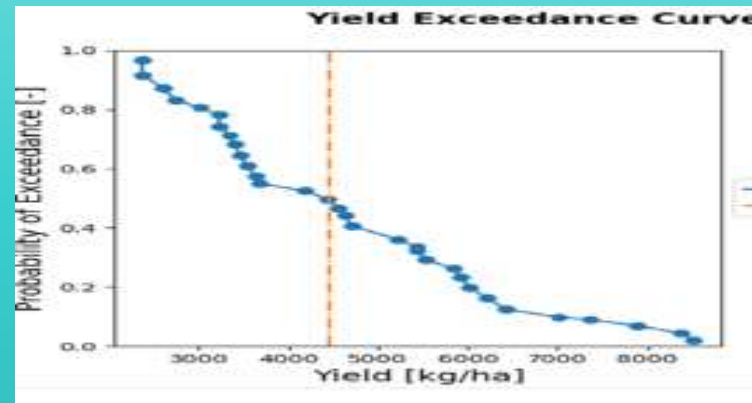


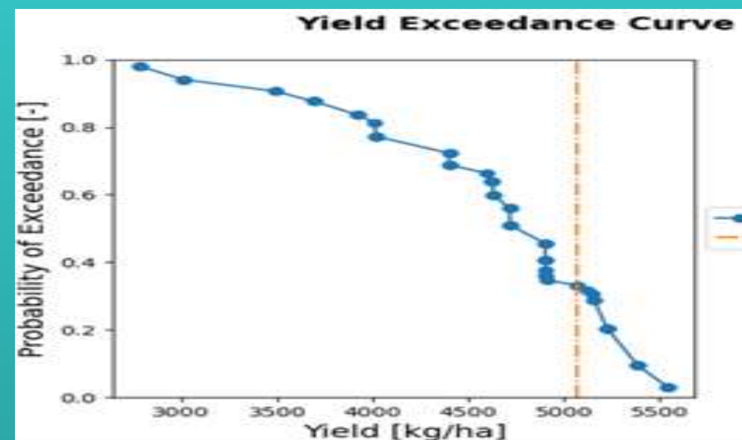


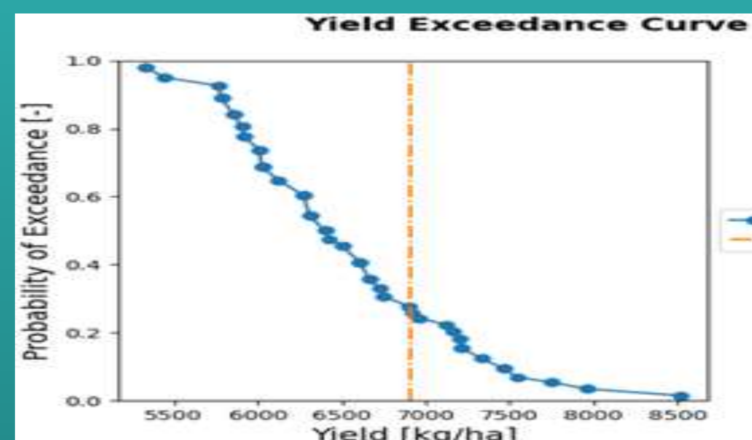


LEFT PANEL: AN, Top Rice; Middle, Maize; and Bottom, Sorghum

RIGHT PANEL: BN, Top Rice; Middle, Maize; and Bottom, Sorghum



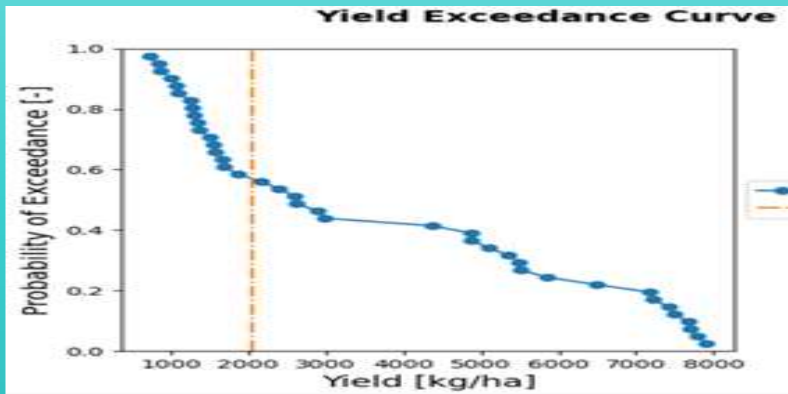




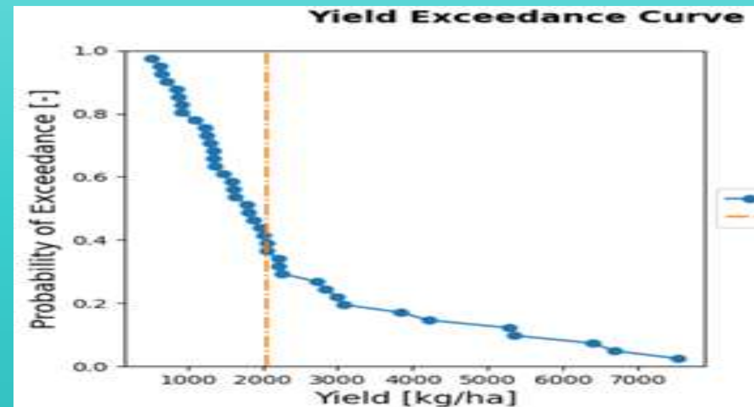
Observations

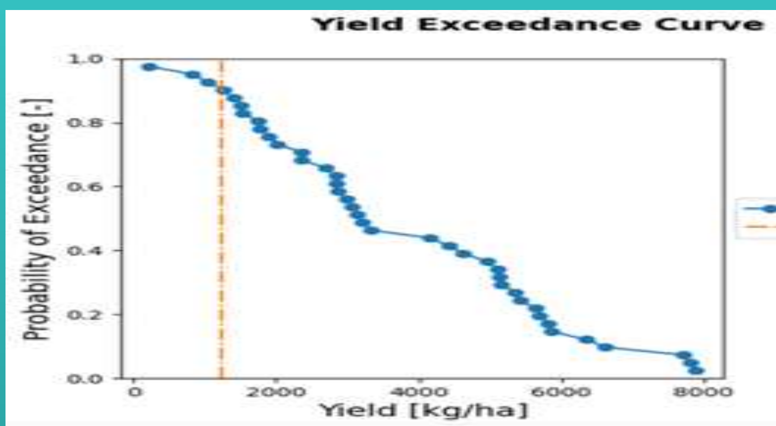
- Mzimba, Malawi is a very high rainfall area with a seasonal mean of 1200 mm.
- Mean yield quantities were nearly 4.5 T/Ha for rice, 5T/Ha for maize and 6.8 T/Ha for sorghum.
- For above-normal rainfall there was a 75% chance for rice to attain yield of 4.5T/Ha.
- For below-normal rainfall, this chance drops to just below 50%.
- For maize the change from above-normal to below-normal rainfall yields the chances drop from nearly 60% to 30%.
- Chances of attaining mean sorghum yield change from about 50% for above-normal to about 30% for below-normal rainfall, respectively.
- Typically, Malawi is virtually uniformly a high rainfall area and as such the other regions analyzed (not shown) depict similar yield amounts using exceedance curves for above-normal and below-normal rainfall situations for the three cultivars.

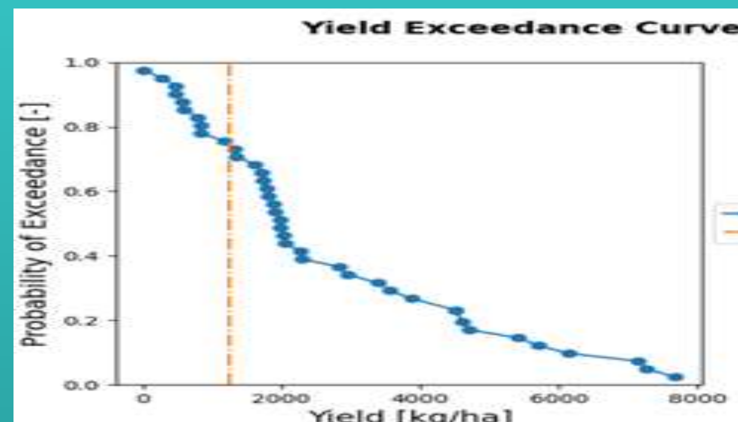
Yield Exceedance Probability for BeitBridge

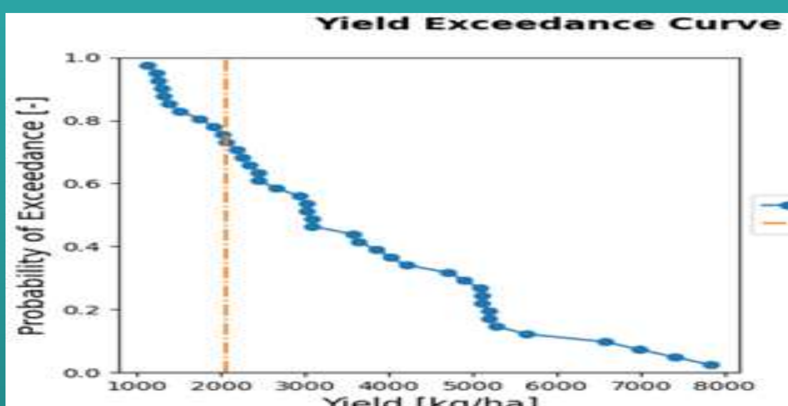


LEFT PANEL: AN,
Top Rice;
Middle, Maize;
and Bottom, Sorghum

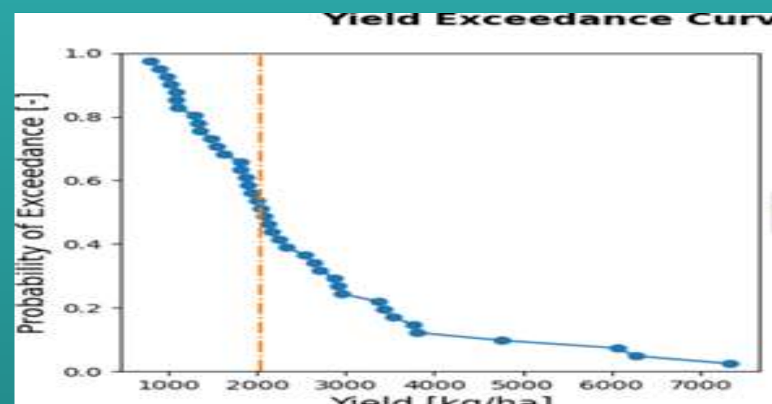








RIGHT PANEL: BN,
Top Rice;
Middle, Maize;
and Bottom, Sorghum



Observations

- Beitbridge, Zimbabwe
- Rice would attain 2.0 tons a hectare, whereas maize is 1.5 T/Ha. However, sorghum would attain close to 4.0 T/Ha.
- Under above normal conditions, rice would be projected to have less than 60% chance of reaching the attainable yield. This chance drops to below 35%, under below-normal conditions.
- For maize the 80% chance level sees a drop from 2.5T/Ha to 1T/Ha from above- to below-normal rainfall.
- The differences in sorghum under both above- and below-normal conditions see drops from about 70% to 50% of meeting the experimental yield.

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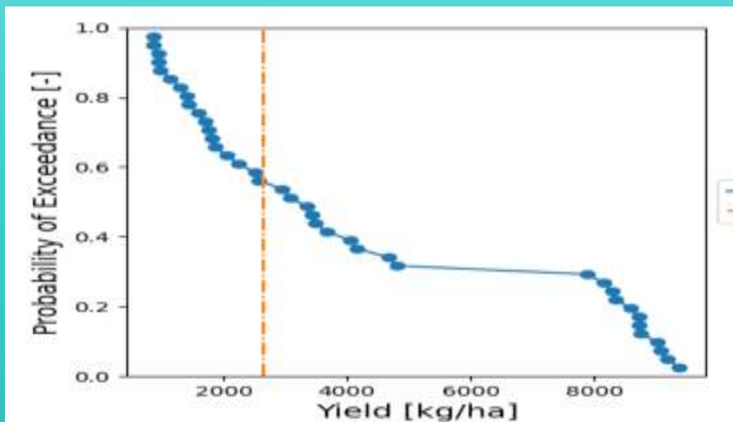
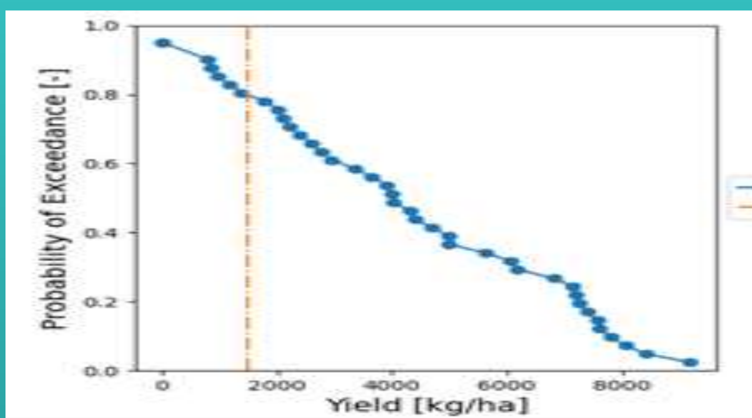
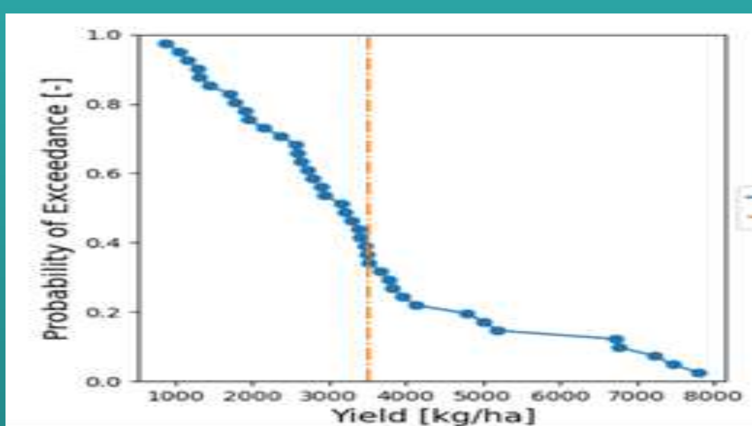
Yield Exceedance Probability for Tutume







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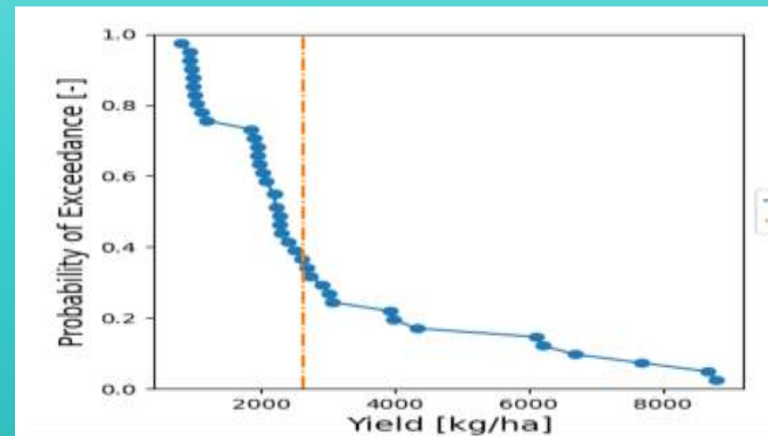
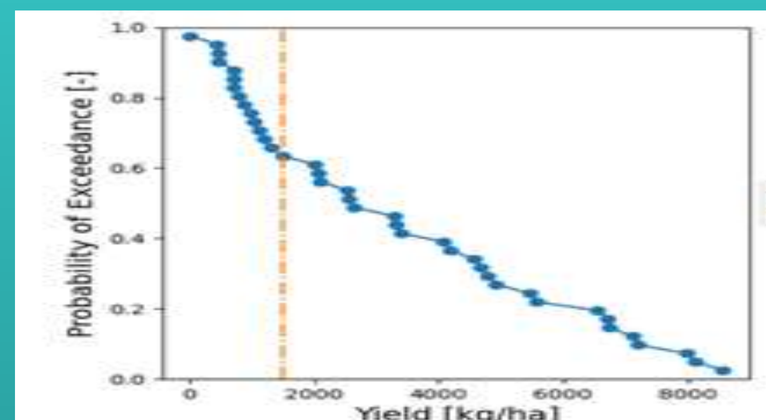
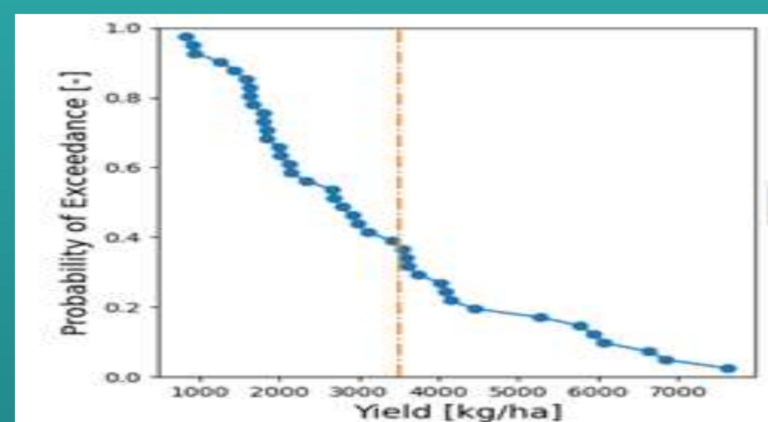






Observations

- Tutume showed mean yields such that rice would have been about 2500 kg/ha, maize, 1600 kg/ha while sorghum would have been 3500kg/ha.

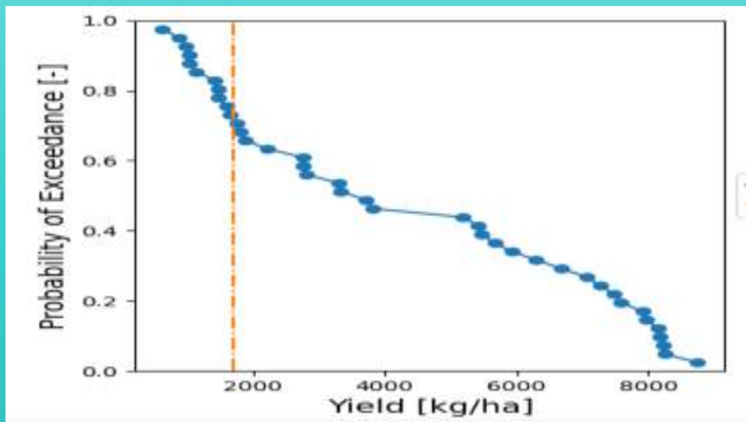
- Using SCF three month in advance, projected to result in above-normal rains there would be 60% chance of obtaining 2500kg/ha for rice which chance would drop to only 30% for below-normal rains.

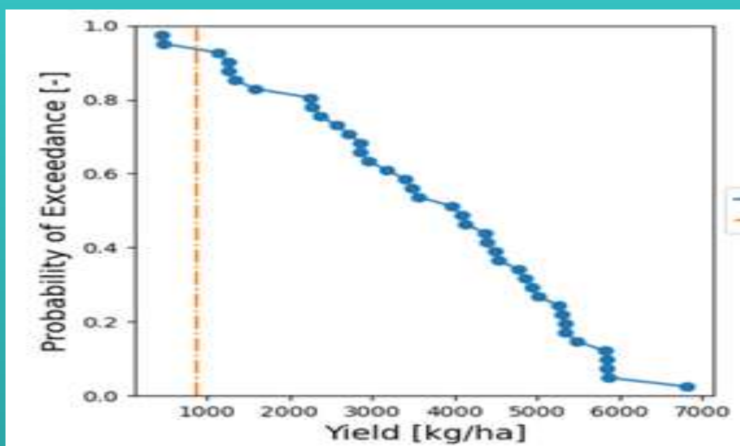
- For maize yield projection there would have been nearly 80% chance of obtaining 1800kg/ha. To achieve the same tonnage if below-normal rains were expected the probability of exceedance would drop to under 70%.

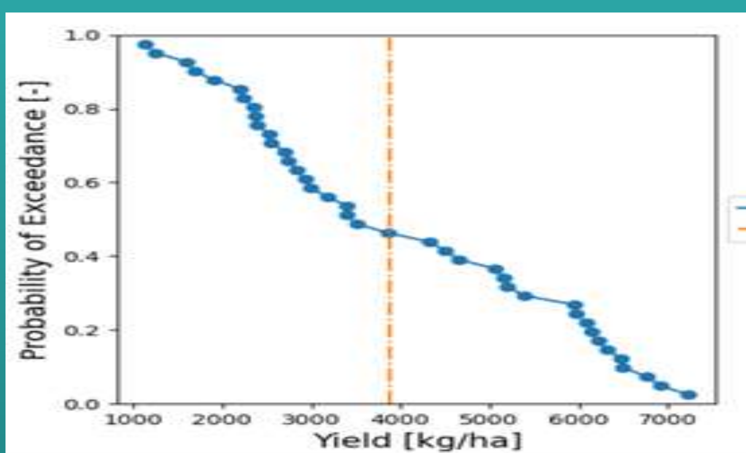
- The best yields were possible for sorghum 3500kg/ha.
- If above-normal rains were projected for the season, then sorghum would have 40% chance of the target of 3500kg/ha. This probability would decrease to 30% for below-normal rainfall expectation.
- In other words the best bet for relatively good production in the area was to grow sorghum.

CIS Based DST Software for Socioeconomic Benefit

Yield Exceedance Probability for Mapai







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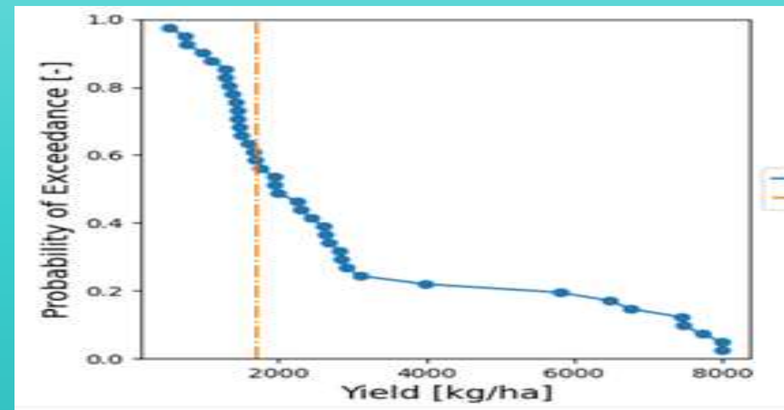

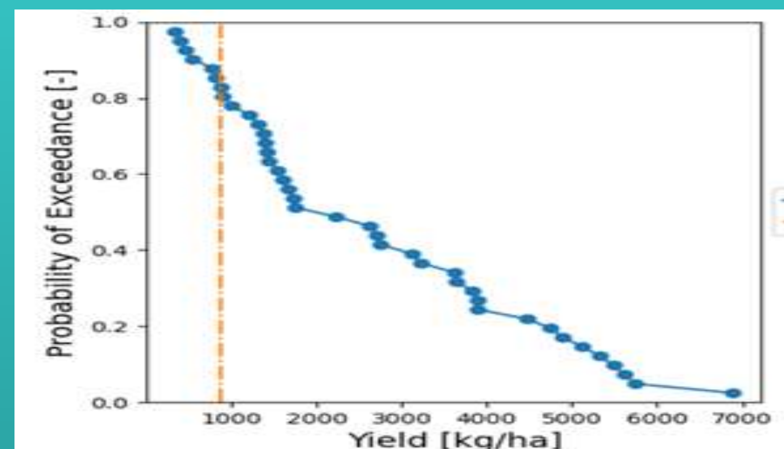

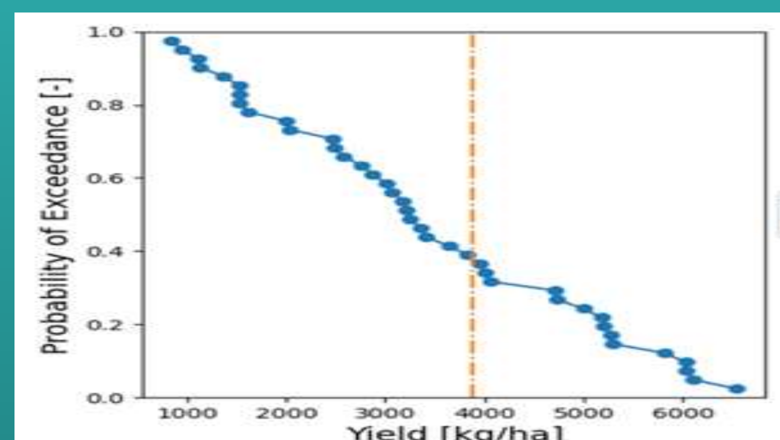

Observations

- Dry area of Mapai, Mozambique
- Rice would attain 1.6 tons a hectare, whereas maize is 0.9 tons a hectare.
- However,
- Sorghum would attain close to 4.0 T/Ha. Under above-normal conditions rice would be projected to have only 70% chance of reaching the attainable yield. This drops to below 60%, under below-normal conditions.
- For maize the 80% chance level sees a drop from 2.5T/Ha to 1T/Ha from above- to below-normal rainfall.
- Interestingly the differences in sorghum under both above- and below normal conditions are slight. The chances of attaining the mean of 4T/Ha drops from about 45% to 40% for above- and below-normal cases.
- It is, therefore, advisable that the option of planting sorghum is preferred.

Exceedance curves as input to DSS

The **scenario generation** would assist the farmer to decide how much of the farm s/he will put under a particular crop for a particular season based on the SCF provided to the farming community and the policy-makers.

The qualitative yield exceedance curves are quite instructive as they vary proportionately in accordance with the respective forecast tercile categories for each of the crop cultivars.

DSS Advisory

SCF/CROP YIELD FORECAST DSS

EXAMPLES OF ADVICE TO FARMERS

Above normal

High rainfall area

70-80% of cropping land for ***long-season seed varieties***; 20-30 % medium seed varieties

Near normal

50-70% of cropping land for ***medium seed varieties***; 15-20% short season seed varieties; 15-20% short season seed varieties

Below Normal

30-40% of cropping land for ***medium seed varieties***; 50-60% short season seed varieties

(continued....)

DSS Advisory

Medium rainfall area

70-80% of cropping land for medium-season seed varieties; 20-30% short seed varieties.

60-80% of cropping land for short-season seed varieties; 15-20 % medium- season seed varieties

50-60% of cropping land for short-season seed varieties; consider letting 30% land unplanted.

Low rainfall area

70-90% of cropping land for short-season seed varieties; 10-20% medium seed varieties

60-80% of cropping land for short-season seed varieties; 15-20% medium- season seed varieties

30-40% of cropping land for short-season seed varieties; consider letting 60% land unplanted

Concluding Remarks

- Food security and agricultural productivity continue to experience challenges in SSA.

- Tapping on the demonstrated SEBs of CIS, the study proposed ways to better apply CIS as decision support systems (DSS) to benefit agricultural production systems. For instance:

- Modified CAMDT is used to generate several crop cultivars capability prediction using SCF;
- Taking full advantage of crop capability prediction models, there is potential for:
  - Risk Management
  - Significant avoidable losses in agricultural production systems;
  - Enhanced productivity efficiencies; and
  - Extending applications of the model in Climate Change Adaptation

- There is need to calibrate crop coefficients.
- AI needs to be considered to fill data gaps and improve on the crop yield prediction tools.

Way Forward

The way forward envisions that there will be appropriate policy formulation and investment in order that the prerequisites for successful implementation of the DSS are met. These should include the following:

- Conducting field experimentation for purposes of calibration and validation of local crop cultivar coefficients as inputs into crop capability models;
- Exploring use of AI in calibration and validation of the models;
- Improvements in crop capability prediction methodologies;
- Training in the use of, and improvements in, the crop yield prediction modelling;
- Conducting of work on extending the crop capability prediction horizon by taking advantage of longest lead times of seasonal climate forecasts;
- M&E i.e. periodic assessments of outcomes of what would have been produced without the availability of forecasts tailored for the particular application of interest;
- Extending the work for use in Climate Change Scenarios such as different Representative Concentration Pathways; and
- Given the similarities of challenges in benefiting from CIS, this study needs to be scaled up to other Sub-Saharan Africa countries.

References

- AgMIP website: https://agmip.org/
- Cantelaube, P. and J. M. Terres (2005), Seasonal weather forecasts for crop yield modelling in Europe. Tellus 57A:476-487
- Carbone G. J. (1993), Considerations of meteorological time series in estimating regional-scale crop yield. J Clim 6:1607–1615
- Divesh Choudhary (2018), Crop Growth Simulation Model for Agriculture. Submitted to Dept. of Agricultural Meteorology, B.A. College Of Agriculture Anand Agricultural University **338110.** DOI: 10.13140/RG.2.2.35505.28008
- de Wit, C.T. and J. Goudriaan (1978), Simulation of Assimilation, Respiration and Transpiration of Crops. Simulation Monograph. PUDOC, Wageningen.
- Drosdowsky W., and L. E. Chambers (2001), Near-global sea surface temperature anomalies as predictors of Australian seasonal rainfall. J. Climate 14 (7): 1677–1687. https://doi.org/10.1175/1520-0442(2001)014<1677:NACNGS>2.0.CO;2
- Garanganga B. J. (2018), Modelling Social and Economic Benefits of Climate Information Services for Disaster Risk Reduction. https://www.uneca.org/.../modelling_social_and_economic_benefits_of_climate_information services, 2018
- Garanganga B J., T Nyakutambwa, F Rutabingwa and J Murombedzi (2021), i. Decision Support System for Agricultural Production in Sub-Saharan Africa. In Proceedings of the Biennial Conference of the Spanish Association for Artificial Intelligence (CAEPIA-20/21).
- Grondona M.O., G.P. Podestá, M. Bidegain, M. Marino and H. Hordu (2000), A stochastic precipitation generator conditioned on ENSO phase: a case study in southeastern South America. J Clim 13:2973 –2986
- Hallegatte S. (2012), A cost effective solution to reduce disaster losses in developing countries: hydro-meteorological services, early warning and evacuation. World Bank Policy Research Paper No. 6058. The World Bank, Washington, D.C. USA.
- Hammer, G. L. and R. L Vanderlip (1989a). Studies on genotype by environment interaction in grain sorghum. I. Effects of temperature on radiation use efficiency. Crop Science 29:370–376.CrossRefGoogle Scholar
- Hammer, G. L. and R. L Vanderlip, (1989b). Studies on genotype by environment interaction in grain sorghum. III. Modelling the impact in field environments. Crop Science 29:385–391.CrossRefGoogle Scholar
- Han, E- J. and A. V. M. Ines (2017), Downscaling probabilistic seasonal climate forecasts for decision support in agriculture: A comparison of parametric and non-parametric approach. Climate Risk Management 18, 2017, Pages 51-65.
- Hoogenboom, G., C. H. Porter, V. Shelia, K. J. Boote, U. Singh, J.W., White, L.A. Hunt, R. Ogoshi, J. I. Lizaso, J. Koo, S. Asseng, A. Singels, L. P. Moreno and J. W. Jones (2019), Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.7 (www.DSSAT.net). DSSAT Foundation, Gainesville, Florida, USA. (https://www.ipcc-data.org/guidelines/pages/weather_generators.html)

References

- Jones, J.W., G. Hoogenboom, C.H. Porter, K. J. Boote, W.D. Batchelor, L. A. Hunt, P. W. Wilkens, U. Singh, A. J. Gijsman, and J. T. Ritchie (2003), DSSAT Cropping System Model. European Journal of Agronomy 18:235-265.
- Katz, R.W. M. B. Parlange, (1993), Effects of an index of atmospheric circulation on stochastic properties of precipitation. Water Resour Res 29:2335 – 2344
- Katz R. W., M. B. Parlange and C. Tebaldi (2003), Stochastic modeling of the effects of large-scale circulation on daily weather in the southeastern US. Clim Change 60:189 –216.
- Marletto V., F. Zinoni, L. Criscuolo, G. Fontana, S. Marchesi, A. Morgillo, M. Van Soetendael, E. Ceotto and U. Andersen (2005), Evaluation of downscaled DEMETER multi-model ensemble seasonal hindcasts in a northern Italy location by means of a model of wheat growth and soil water balance. Tellus 57A:488 – 497
- Mearns L. O., C. Rosenzweig C and R. Goldberg (1997), Mean and variance change in climate scenarios: methods, agricultural applications, and measures of uncertainty. Clim Change 37: 367– 396
- SADC (September, 2016), Regional Humanitarian Appeal, Addendum. https://www.sadc.int/files/2014/7463/4292/Appeal_Document_ADDENDUM_20160923.pdf
- Tall A, J. Y. Coulibaly and M. Diop (2018), Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. Climate Services 11, 1-12;https://doi.org/10.1016/j.cliser.2018.06.001).
- Tall, A. and J. Njinga, (2013), Developing a methodology to evaluate climate services for farmers in Africa and South Asia workshop report. Copenhagen, Denmark: CGIAR Program on Climate Change, Agriculture and Food Security. Retrieved from: www.ccafs.cgiar.org. Google Scholar).
- Tsuji, G.Y., 1998. Network management and information dissemination for agrotechnology transfer. In: Tsuji, G.Y., Hoogenboom, G., Thornton, P.K. (Eds.), Understanding Options for Agricultural Production. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 367_/381
- UNECA (2020), Socio-Economic Benefits for Climate Information Service as applied to Disaster Risk Reduction, in press.
- Wilks D. S. (1992), Adapting stochastic weather generation algorithms for climate change studies. Clim Change 22:67– 84
- Wilks, D. S. (2002), Realizations of daily weather in forecast seasonal climate. J Hydrometeorol 3: 195 –207.
- Woolhiser D. A., T.O. Keefer and K. T. Redmond (1993) Southern oscillation effects on daily precipitation in the southwestern United States. Water Resour Res 29:1287–1296.

Thank You For Your Attention

Socioeconomic Benefits from Climate Forecasts for Action

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