USING EARTH OBSERVATION AND ANCILLARY DATA SOURCES AS ALTERNATIVE TO HOUSEHOLD SURVEYS FOR REGIONAL INTEGRATED ASSESSMENTS

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iCROP 2016
Berlin 16 March 2016
Various regions of the world are undertaking Regional Integrated Assessments (RIA) following AgMIP protocols.

These protocols were created to link climate, crop and economic modelling through information technology components, to assess the impact of climate change on future agricultural systems.

The Regional Integrated Assessments rely on household surveys to supply the necessary data inputs to the crop and economic models.

In South Africa no such detailed survey data could be obtained and an alternative method had to be developed.
A framework was developed and tested at:

- **District** scale for the whole RIA and
- **National** scale to crop model output level (Climate change & Crop estimates).
Although most dynamic crop models have been developed and tested for the scale of a homogeneous plot, applications related to crop estimates and climate change are often at **broader spatial scales** that can incorporate considerable heterogeneity.

The most adopted approaches to overcome this limitation are to either model:
- representative sites (points),
- homogeneous regions (vector) or
- partitioning into grid cells (raster).

The **Maize crop field mask** was developed using:
- Satellite imagery
- Producer independent crop estimates surveys (PICES) – aerial surveying and
- Crop type classification.
Landsat and SPOT images were used to **digitize field boundaries** (updated every ±5 years).

The coverage of South African field crop boundaries is **14 million ha.**

The field crop boundary database is used as basis for an aerial-survey, identifying fields planted to different crops. Also known as the **Producer Independent Crop Estimates Survey (PICES).**

The PICES points are used for satellite image calibration and **crop type classification.** Recalibrated annually.
Maize Crop Mask - Methodology

- To create the **maize crop mask**, all fields that have been identified to have been planted to maize for the period 2006 to 2009 were identified and collated into one database.
- **± 130 000 maize fields** on a national scale.

<table>
<thead>
<tr>
<th>District</th>
<th>Total area arable fields (ha)</th>
<th>Area planted to maize dryland (ha)</th>
<th>Number of dryland fields</th>
<th>Area planted to maize irrigation (ha)</th>
<th>Number of irrigated fields</th>
<th>% of total area arable fields planted to maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bethlehem</td>
<td>127 771</td>
<td>93 510</td>
<td>4 945</td>
<td>595</td>
<td>44</td>
<td>74</td>
</tr>
<tr>
<td>Bloemfontein</td>
<td>121 604</td>
<td>44 115</td>
<td>1 512</td>
<td>5 533</td>
<td>422</td>
<td>41</td>
</tr>
<tr>
<td>Bothaville</td>
<td>179 032</td>
<td>152 798</td>
<td>4 548</td>
<td>1 123</td>
<td>89</td>
<td>86</td>
</tr>
</tbody>
</table>
Climate - crop model inputs

Long term predictions (climate change)

- **District scale** for RIA: University of Cape Town’s Climate systems analysis group (CSAG).

- **National scale**: Data from the University of KwaZulu-Natal. Based on quaternary catchments (1950-1999) for 5 GCMs for mid (2045-2065) and end (2080-2100) of century.

- **GCM's**: CCSM4, GFDL-ESM2G, HadGEM2-ES, MICROC5 and MPI-ESM-MR.
- **Mid-century** (2040-2070) under RCP8.5.
- Baseline CO₂ level 360 ppm and future 571 ppm.

Short term predictions (in season)

- Single season up-to-date and projected climate using an analogue model (Crop estimates)

**Historical Climate Conditions**
- 1980-2010
- CO₂ 360 ppm

**Future Climate Scenario’s**
- 2040-2070
- CO₂ 571 ppm
- RCP 8.5

Use climate data **to-date** for current season
Use **like year** (analogue year) to complete current season’s climate based on a calculated D-Index.
Soil properties were derived using the **land type maps** and identifying soil series suitable for maize production.

- All soils with mechanical restriction, a depth of < 400 mm and a clay content > 50% within each Terrain Unit (TU) (1:50 000 scale) were eliminated.

- To determine the soil properties for each field, firstly the weighted averages of the soil properties were calculated for each TU. Secondly, the soil properties in each field were calculated based on the percentage representation of each TU within a field using zonal statistics (GIS). This results in each field having an unique soil description.

- Drained upper limit (DUL), lower limit (LL) and saturation (SAT), were derived from pedo-transfer functions based on clay content.

- Pedo-transfer functions developed for a South African Agro-hydrological model (ACRU) were used to calculate bulk density, drainage rate, the evaporation limit and organic carbon.

- Runoff was based on a slope and hydrological grouping.
• Free State province was divided into two zones, i.e. above and below 500 mm rainfall per annum.

• Within the Free State 1542 samples obtained from objective yield surveying over a six year period (2008-2013) were used to calculate the proportion for row widths, planting dates and plant populations.

• The same proportion was used to assign the management strategies to all the fields within the Free State.

• Fertilization was based on the average modelled 50 year yield potential of each field.
Field

Probability of exceedance of inter-annual variation in baseline and future irrigated maize yields based on five different GCMs for a single dryland field in the Bloemfontein district for the mid-century period (2040-2070) under RCP8.5.

Quinary Catchment

Yield of fields (kg/ha) averaged over quinary catchments for the Bethlehem district, mid-century period (2040-2070) under RCP8.5.

District

Box plots of inter-annual variation in baseline and future irrigated maize yields based on five different GCM's for the Bothaville district for the mid-century period (2040-2070) under RCP8.5.
Simulations of dryland maize production for the **Free State Province** using DSSAT with the auto replicate planting option of the QUAD-UI.

Historical yield data includes irrigation. In 1995/96 South Africa changed from a single channel market system to a open market system and farmers had to adapt to international market price variations. This resulted in optimisation of all crop husbandry aspects, the increase of area under irrigation, not planting on marginal soils, use of more GMO varieties.

Means of simulated dryland maize yields under mid century (2046 - 2065) climatic conditions, averaged from outputs of 5 GCMs (top left), from each individual GCM (bottom smaller maps) and (top right) for baseline climatic conditions (Durand and Schulze, 2014).
Percentage change in production from current baseline (1980-2010) under RAP 1 Future (“Positive development pathway- low challenges to adaptation simulated using crop (DSSAT & APSIM) and economic (TOA-MD) models for the Bethlehem district in the Free State. 
The framework developed, using GIS and the QUAD-UI tool, allows for the rapid assembly of large amounts of crop model input data that is representative of the maize cropping systems of South Africa, which was previously not possible.

For climate change studies, using climate data representing historic and different future climate change projections based on different global circulation models (GCMs), it was found that the framework allows for the large amount of simulations required in these studies (~45 million) to be easily set up and executed.

Using climate data from a single season up-to-date and projected climate using a weather analogue model allows for crop yield estimates to be made and summarised to provincial level as required by the Crop Estimates Committee.

The link to the GIS also allows for these large number of simulation outputs to be post processed that enable the field level data to be summarised to different spatial levels such as farms, catchments, district, provincial or national. This in turn can then be presented in table, graph or map format.
Conclusions

• Linking satellite imagery derived and ancillary survey data to crop and economic models proves to be a **good alternative method** to replace household survey data to assess impacts of climate change on maize production at field to district level in South Africa.

• There is the opportunity to link even more spatially generated products in to the framework e.g. gridded soil water index.

Acknowledgements

This research was sponsored by **USDA** and **UKAID**.
Technical support from **AgMIP** (Columbia University, University of Florida, Oregon State and NASA)
**PICES data and field crop boundaries:**
Maize Trust
Rona Beukes – South African National Departement of Agriculture
Fanie Ferreira - GeoTerraImage
Eugene du Preez – SIQ
**Land type data:**
Hein Beukes and Marjan van der Walt– ARC-ISCW