CHARACTERIZING ECOSYSTEM RESPONSE TO CLIMATE CHANGE IN SOUTH AFRICA USING EARTH OBSERVATION TECHNOLOGY

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Outline

- Introduction and Climate Overview
- Earth Observation Applications (Natural Vegetation and Agro-ecosystems)
- Adaptive Options and Interventions
- Concluding Remarks
Introduction

• Water is critical for development, economic growth and better life.
• Climate plays a significant role to the country’s economic development.
• Natural and anthropogenic activities drives the change in climate by altering the Earth’s energy budget.
• The IPCC recognizes a clear cause and effect relationship between the enormous growth in the emissions of GHGs, escalating global average temperatures and extreme weather events.
• This therefore calls for positioning and reorientating various sectors in order to realign development with the changing climate (structural and economic reforms).
• Applications of remote sensing are expected to contribute to guidance, advice and direction for reorientation and developmental response in light of the changing climate.
Average annual rainfall & water resource situation

South Africa is characterized by a skewed distribution of rainfall, high solar radiation and high evaporation rate.

- Rainfall high: 1500mm N & E; reduces towards S & W: 100mm;
- Water availability is accordingly skewed in terms of distribution (estimated at 650 billion m$^3$);
- Evaporation rates far exceed precipitation (relatively higher in areas where it rains less);
- Water is not always fit for use, even under natural conditions;
- This translates into water scarcity (even before taking climate change or human induced impacts into account);
- Increased occurrence of extreme climate events.

WRC-UNEP, 2006
Water and SA’s economic hubs

8% of land area
- provide 50% of the surface water
- support half of SA’s population
- support 70% of the economy

Strategic Water Resource Areas

Projected change

**RCP 4.5:** Annual temperature change (ºC) relative to 1985-2005

<table>
<thead>
<tr>
<th>2046 - 2065 (+50 years)</th>
<th>2076 - 2095 (+80 years)</th>
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**RCP 8.5:** Annual temperature change (ºC) relative to 1985-2005

2046 - 2065 (+50 years)

**RCP 4.5:** Annual rainfall change (mm/month) relative to 1985-2005

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**RCP 8.5:** Annual rainfall change (mm/month)

2046 - 2065 (+50 years)

SAWS WRC project 2247
Predictability of hydroclimatic variability over eastern South Africa under climate Change

WRC Project K5/2457

Projected changes in the 11-year moving average of summer rainfall (top) and the variability of rainfall (bottom) over the mega-dam area of South Africa under low mitigation, for a single downscaling. WRC K5/2457 considers the largest ensembles of projections generated for this region to date.

CSIR-CSIRO-CHPC-WRC
Drought patterns over Southern Africa

These are the 12 major types (or patterns) of regionally extensive droughts in southern Africa. The colours show the values of a drought index (Standardized Evapotranspiration Index). The index is calculated from surface water balance (rainfall minus potential evapotranspiration). Hence, it account for the influence of global warming. A negative value indicates a dry condition (drought), while a positive indicates a wet condition.

The four drought patterns at the edges show the extremes cases of drought patterns:
- **Top-left** => The entire region is experiencing drought
- **Bottom-right** => The entire region is experiencing a wet condition
- **Top-right** => The northern half is experiencing a wet condition, while the southern half is experiencing drought.
- **Bottom-left** => The northern half is experiencing drought, while the southern half is experiencing a wet condition.
## SA’s vulnerability to climate change

<table>
<thead>
<tr>
<th>System/Conditions</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>already fully allocated; reductions in availability, increased frequency of extremes</td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>Food security, most scenarios suggest adverse impacts in the agricultural and forestry sectors, with emphasis to small-scale farmers,</td>
</tr>
<tr>
<td><strong>Human health</strong></td>
<td>strong interactions with environmental quality and current disease burden</td>
</tr>
<tr>
<td><strong>Extreme events</strong></td>
<td>weather-related impacts are already exacerbated by poor land management</td>
</tr>
<tr>
<td><strong>Natural resources</strong></td>
<td>degradation trends likely worsen without addressing sustainable management issues; opportunities for increasing resilience of rural and urban communities</td>
</tr>
<tr>
<td><strong>Human settlements and livelihoods</strong></td>
<td>emerging understanding suggests significant and adverse impacts</td>
</tr>
</tbody>
</table>

Source: DEA
Earth Observation Applications
CLIMATE CHANGE AND NATURAL FOREST DECLINE

Kephe, Petja and Kabanda, 2015
Climatic trends

**Rainfall**

- Actual rainfall; 5-year moving average; Trend

Climatic trends: Rainfall
Climatic trends...

**Mara**

\[ y = 0.0425x + 28.576 \]

**Levubu**

\[ y = 0.0205x + 27.815 \]
Change detection

1989-1998

1998-2008
CAUSAL FACTORS: Anthropogenic Activities in the Soutpansberg
Observing and Monitoring Changing Climate
Inter-annual shifts in rainfall distribution

Accumulated NDVI and Rainfall for 1995/1996
Wet Season

Accumulated NDVI and Rainfall for 1991/1992
Dry Season

Petja et al, 2004
Pasture Productivity under different Climatic Regimes

- Production areas demarcated and managed in line with projected changes.
- Threat to degradation quantified in relation to stocking density.
Expanding drought window due to increased variability (processed and calculated using satellite derived drought index over 22 years for summer rainfall areas)

Source: Petja et al., 2008

Declining Area for Summer Grain Production

VCI = (NDVI - NDVI_{min})/(NDVI_{max} - NDVI_{min})

where \( NDVI = \frac{(NIR - Red)}{(NIR + Red)} \)

Depicts mapping of drought prone areas
Climate and Agricultural Production

- Positive relationship between climate change drivers and agricultural production.
- A change in climate may affect agricultural production negatively or positively.
- Crop stress, pest and diseases, crop failure etc.

Nesamvuni et al, 2009, Lekalakala, 2011
Monitoring crop response

- Vegetative response depicted over a growing season.
- Anomalies detected.

SPOT VEG

NDVI time series

Sugarcane
Resultant Impacts on Crops

- Crop responses to temperature, precipitation, CO$_2$.
  - Increased crop vigour (positive response)
  - Crop mortality (extreme temperatures – decreased yields)
  - Flood damage
- Changing water availability for irrigation.
- Changing lengths of growing periods and reliability of rainy season.
- Plant diseases.
BUSH ENCROACHMENT

Legend
- Towoomba Research Station
- Bela Bela

South Africa

Limpopo Province

Bela-Bela Local Municipality

Towoomba Research Station

Legend
- Towoomba Research Station
- Bela Bela

0 5 10 20 30 Kilometers

N
Adaptive Options and Interventions

- Routine applications of EO technology in operational management.
- Integration of climate change adaptation strategies into development and spatial plans.
- Protection of vegetated areas affecting local climate regimes.
- Afforestation and agroforestry projects in deforested areas.
- Land use change.
- Land use policy should address mechanisms for mitigation and adaptation to the challenges brought by changes in the climate.
Adapted Land Use in light of the Changing Climate

- Differentiated land use.
- Classified biomes
- Sensitive ecosystems

Site-Specific Development Planning
### STERKFONTEIN 1

#### CLIMATE

<table>
<thead>
<tr>
<th>Mean Annual Rainfall</th>
<th>Rainfall Coeff Variation</th>
<th>Refer Crop Evaporation</th>
<th>Mean Annual Temp</th>
<th>Mean Growth Season Days</th>
<th>Growth Season Start</th>
<th>Growth Season End</th>
</tr>
</thead>
<tbody>
<tr>
<td>544 - 572</td>
<td>26.5</td>
<td>1419.00</td>
<td>16</td>
<td>166 - 170</td>
<td>Oct 06 - Oct 08</td>
<td>Mar 23 - Mar 25</td>
</tr>
<tr>
<td>Avg Montly Rainfall</td>
<td>Jan</td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
<td>Jun</td>
</tr>
<tr>
<td>170.00</td>
<td>14.00</td>
<td>115.00</td>
<td>85.00</td>
<td>28.00</td>
<td>25.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Avg Max Daily Temp</td>
<td>25.83</td>
<td>25.47</td>
<td>24.83</td>
<td>22.87</td>
<td>20.97</td>
<td>18.30</td>
</tr>
<tr>
<td>Avg Mean Daily Temp</td>
<td>20.37</td>
<td>19.73</td>
<td>18.93</td>
<td>16.27</td>
<td>13.93</td>
<td>10.63</td>
</tr>
<tr>
<td>Avg Montly Rainfall</td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>14.00</td>
<td>17.00</td>
<td>25.00</td>
<td>125.00</td>
<td>149.00</td>
<td>152.00</td>
<td></td>
</tr>
<tr>
<td>Avg Min Daily Temp</td>
<td>2.67</td>
<td>4.97</td>
<td>8.85</td>
<td>10.80</td>
<td>12.38</td>
<td>13.55</td>
</tr>
<tr>
<td>Avg Max Daily Temp</td>
<td>18.83</td>
<td>21.13</td>
<td>24.40</td>
<td>24.57</td>
<td>24.73</td>
<td>26.00</td>
</tr>
<tr>
<td>Avg Mean Daily Temp</td>
<td>11.20</td>
<td>12.77</td>
<td>16.27</td>
<td>18.33</td>
<td>19.03</td>
<td>19.77</td>
</tr>
</tbody>
</table>

#### Heat Units

<table>
<thead>
<tr>
<th>Winter</th>
<th>Summer</th>
<th>Min</th>
<th>Max</th>
<th>Avg</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>516.67</td>
<td>1516.67</td>
<td>13.35</td>
<td>25.51</td>
<td>19.43</td>
<td>4.49</td>
<td>19.81</td>
</tr>
</tbody>
</table>

#### Average Summer Temp

| Avg | 12.15 |

#### Average Winter Temp

| Avg | 12.15 |

#### CROP SUITABILITY

<table>
<thead>
<tr>
<th>Soil Unit</th>
<th>Field Nr</th>
<th>Area (Ha)- Effective</th>
<th>Optimal</th>
<th>Suitable-Optimal</th>
<th>Suitable</th>
<th>Marginal-Suitable</th>
<th>Marginal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av60</td>
<td>St1-1</td>
<td>10.31</td>
<td>Potatoes</td>
<td>Onions; Drybeans</td>
<td>Avo; Tomatoes; Okra; Cassava; Kikuyu</td>
<td>Butternut; Pepper Dew; Maize; Sorghum; Millet; Canola; Panicum; Cenchrus</td>
<td>Spinach; Sunflower; Ground Nuts; Lucerne</td>
</tr>
<tr>
<td>Cv80</td>
<td>St1-4; St1-5</td>
<td>20.34</td>
<td>Potatoes</td>
<td>Onions; Spinach; Okra; Drybeans</td>
<td>Tomatoes; Butternut; Pepper Dew; Cassava; Maize; Sorghum; Millet; Ground Nuts; Kikuyu</td>
<td>Canola; Sunflower; Panicum; Cenchrus</td>
<td>Banana; Lucerne</td>
</tr>
<tr>
<td>Hu100</td>
<td>St1-2</td>
<td>74.25</td>
<td>Potatoes; Sorghum</td>
<td>Onions; Spinach; Okra; Cassava; Maize; Millet; Drybeans; Kikuyu</td>
<td>Tomatoes; Butternut; Pepper Dew; Canola; Sunflower; Ground Nuts; Panicum; Cenchrus</td>
<td>Lucerne</td>
<td>Banana; Vetch</td>
</tr>
<tr>
<td>Hu60</td>
<td>St1-6</td>
<td>34.97</td>
<td>Potatoes</td>
<td>Onions; Drybeans</td>
<td>Tomatoes; Okra; Cassava; Kikuyu</td>
<td>Butternut; Pepper Dew; Maize; Sorghum; Millet; Canola; Panicum; Cenchrus</td>
<td>Spinach; Sunflower; Ground Nuts; Lucerne</td>
</tr>
<tr>
<td>Hu80</td>
<td>St1-3; St1-9</td>
<td>69.40</td>
<td>Potatoes</td>
<td>Onions; Spinach; Okra; Drybeans</td>
<td>Tomatoes; Butternut; Pepper Dew; Cassava; Maize; Sorghum; Millet; Ground Nuts; Kikuyu</td>
<td>Canola; Sunflower; Panicum; Cenchrus 33</td>
<td>Banana; Lucerne</td>
</tr>
<tr>
<td>Lo40</td>
<td>St1-7; St1-8</td>
<td>4.12</td>
<td>None</td>
<td>Onions</td>
<td>Cassava; Drybeans</td>
<td>None</td>
<td>Maize; Sorghum; Millet; Kikuyu</td>
</tr>
</tbody>
</table>

**Total:** 213.39
Concluding remarks

• Climate plays a significant role to rural and regional development.
• Increased inter-annual and intra-seasonal variability climate threaten most development sectors.
• Changes and shifts in climate => socio-economic, agricultural and environmental spheres
• EO technology presents more opportunities to characterize and observe the frequency of climatic anomalies and variation to aid in mitigation and adaptation strategies.
• More action is required at local scale in terms of adaptive response and mainstreaming.
United sectoral and inter-sectoral response will defeat the might of climate change.
Acknowledgements

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