Transdisciplinarity within South Africa's global change research: How (well?) are we doing?

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The Global Change Programme (GCP) of the Department of Science and Technology (DST) of South Africa is one of the 'Grand Challenge' programmes that comprise a 10-year Innovation Plan (2008–2018), which aims to transform South Africa into a greater knowledge-based economy through stimulating transdisciplinary research to resolve, inter alia, specific energy, economy, society and technology needs. Meeting these challenges epitomises the necessity of effective transdisciplinary research, which can be defined as research specifically orientated to resolve 'real-world' (i.e. encompassing policy-driven research toward societal benefit) problems that are too complex and multidimensional to be answered by singular research disciplines.[1] We present a first-order evaluation of the transdisciplinary capacity building within the GCP programme at its halfway stage, with an aim to test its effectiveness.

We base our analyses of transdisciplinarity after calculating the level of transdisciplinary research across the various themes presented at the 2nd Biannual Conference for Global Change (CGC), held in early December 2014, at the Nelson Mandela Metropolitan University in the Eastern Cape. Our model evaluates links created between the research papers to the overarching themes of the conference by considering key words/phrases within each research paper. These links are inculcated within this model to establish the network of interconnectivity across the conference research themes and its success in catalysing transdisciplinarity research amongst young graduate students in South Africa.

We specifically highlight non-linkages between themes that are known to be important to meeting Global Grand Challenges. Non-linkages are also related to shortfalls in accelerated policy development and implementation of important facets relating to the Innovation Plan. We show that an analysis of this nature helps to highlight the need to re-direct some of the key research links to better facilitate the aims of South Africa's Grand Challenges.

Global change background

In 2008, the DST launched its 10-year Innovation Plan for South Africa: *Innovation towards a Knowledge-based Economy 2008–2018.* This plan identified five challenges on which efforts were to be focused to bring about social, economic, political, scientific and technological benefits, namely:

1. The 'Farmer to Pharma' value chain to strengthen the bio-economy
2. Space science and technology
3. Energy security
4. Science and technology for global change with a focus on climate change
5. Human and social dynamics

The scale of the proposed key knowledge and innovation priorities is ambitious, and DST has thus described them as Grand Challenges. One of the Grand Challenges – the Global Change Grand Challenge – is related to global change, with a focus on climate-linked changes in the Anthropocene.[2] These climate changes are caused by ever-increasing human activities, including environmental and social disruptions, and often have perceived negative connotations, e.g. rapid biodiversity collapse, increasingly severe weather fluctuations, extensive land degradation, energy–food–water insecurity and growing social and economic inequality and unrest. Global change research aims to investigate how these effects are interconnected and how human behaviour may be stimulated to mitigate negative side-effects as much as possible. The *10-Year Global Change Research Plan for South Africa* is inter alia notable for the following reasons:

1. It adopts a systems approach, and is strongly interdisciplinary.
2. It is based on the unique geographical location and developmental challenges of South Africa and is grounded in its socio-ecological needs.
3. It aims to advance a better understanding of the functioning of the earth system and to support efforts to respond effectively to changes.
4. It has a strong focus on climate change, and takes into consideration contemporary debate and discussion in this regard.
5. It supports making a contribution to the international knowledge base as well as to locally relevant and required research, and it is intended to be policy relevant.

Each of these Grand Challenges was designed to stimulate multidisciplinary thinking and to challenge the country's researchers to answer existing questions, increase interdisciplinary collaboration and develop new technologies. The success of the Innovation Plan therefore clearly hinges largely on successful transdisciplinary research and an understanding that selective and singular research themes will not be able to realise its goals.Transdisciplinary research evokes an evolution of these themes through learning from the logic among them, creating perpetual knowledge gain.[3,4] This mechanism is also vital for successful policy-driven research.[5] Evaluating the level of transdisciplinary research has remained largely underdeveloped.[6,7] The most common methodology used for evaluation is formal surveying among researchers and stakeholders and numerical analyses of captured data.

Models of this nature have been applied toward designing and assessing research in specific fields, e.g. in building linkages between health and social sciences[8-12]; in methods for defining research related to ecological economics[13] and in cognitive informatics and computer sciences[14]. We now consider a new approach by evaluating discourse at a recent scientific conference toward evaluating the level of transdisciplinary research.

At the start, the Global Change Research Plan of DST identified four major cross-cutting knowledge challenges – understanding a changing planet, reducing the human footprint, adapting the way we live and innovation for sustainability – and a further 18 key research themes (for more details the reader is directed to: http://www.gov.za/documents/global-change-grand-challenge-national-research-plan). For 5 years now, the Global Change Grand Challenge initiative has supported science and technology as well as key socio-economic development and environmental research projects across the country at most universities and national research institutes, to meet these challenges. It is worth asking therefore how successful this plan has been, and what further challenges should be met to enable success.

Here, we present a numerical model for analysing the level of transdisciplinary research shown within the GCP. To do this, our model is applied to the Conference for Global Change (The full conference programme is available from http://globalchange2014.nmmu.ac.za/Programme). This conference was chosen because it epitomises the research (Figure 1) being undertaken within the GCP and the progress toward resolving its specified Grand Challenges.

A method for analysing transdisciplinarity

The level of the transdisciplinary research encompassed within the GCP was calculated by considering all research papers presented during the conference (i.e. the themes denoted in Figure 1). A numerical model was built to inculcate how often key words or phrases related to each research paper could be linked to the various themes of the conference. Where a research paper was related to a theme, a link was created between the paper and each related theme. This link serves as a level of transdisciplinarity between research and theme. Using this model, we can assess each research paper within the conference, calculating total linkages and using this total as a proxy for the level of transdisciplinary research. The relation between the research papers and themes can be denoted as:

$$RTn \subseteq Tn, \qquad \text{Equation 1}$$

where *RTn* represents the number of research papers presented in the various themes, with *Tn* denoting the total number of different themes. The level of transdisciplinary research is then calculated as:

$$\sum_{i=Ta}^{Tn} \frac{k(RT(a,b,c...n) \approx kRTn}{RTn}, \qquad \text{Equation 2}$$

where *Tn* is again the total number of themes (i.e. as shown on Figure 1), *Ta* is the first theme (i.e. Poverty) and *k* represents a key word/phrase used as linkage. *RT* represents the individual research paper in each theme (*a, b, c …n* representing the individual papers presented), with *RTn* again being the total number of research papers in each theme. Once equated, the results are plotted and interpolated on a graph where the themes comprise both axes. This approach produces a graphical representation in which the level of transdisciplinary research forms linkages across the conference themes. A graphical example (using the Economic session of the conference) illustrating how the model functions is shown in Figure 2.

Results of the analysis

An overview of themes showing transdisciplinary research within the conference is shown in Figure 3. A total of 164 transdisciplinary linkages were created from the 234 research papers. Figure 4 shows a graphical representation of how these linkages are distributed across all the research themes. Circles display linkages with their size and colour highlighting the level of transdisciplinary research linkage. Where no circles are shown, no linkage between themes is implied.

Lessons learned

The results of the numerical model indicate that the following themes are most often incorporated within individual research papers (Figure 3): Monitoring (26%), Climate (10%), Economics (10%), Species (8%), Conservation (8%), Ecosystems (7%), Ocean (6%), Modelling (6%) and Agriculture (5%). Similarly, these themes form the most common transdisciplinary linkage across several themes (Figure 4), e.g. Monitoring–Remote Sensing/Climate/Species, Economics–Mining, and Agriculture–Species.

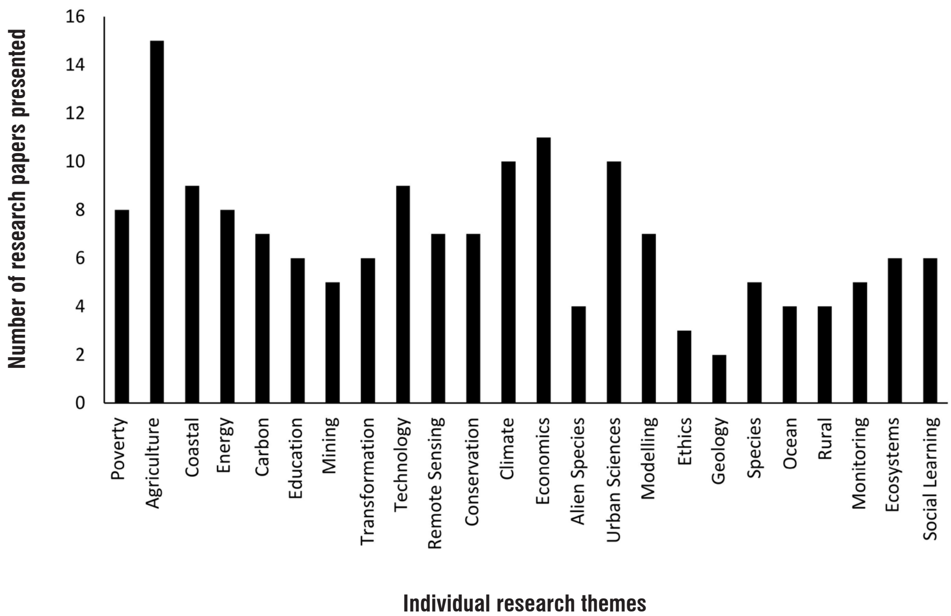

Figure 1: Breakdown of the number of presentations within each theme during the Conference for Global Change.

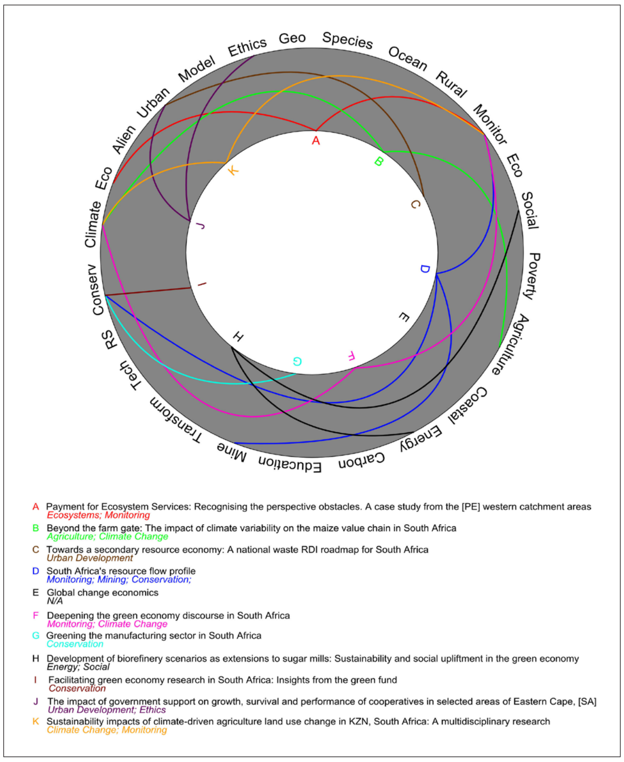

Figure 2: A graphical illustration, based on the 'Economic' session of the 2014 Conference for Global Change, of how transdisciplinary linkages are created within the model. Themes are denoted along the outer circle and the various research papers presented within this session along the inner circle. The titles of the research papers is given in the key.

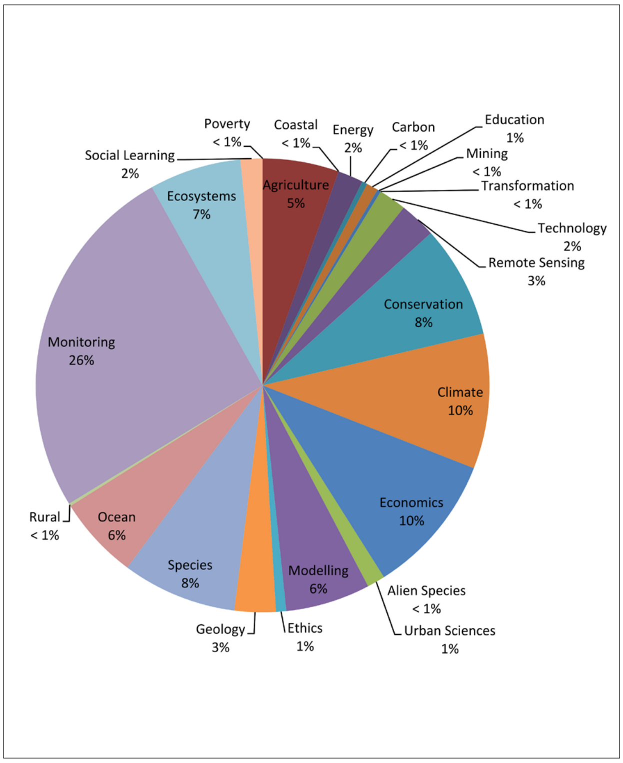

Figure 3: Overview of the most transdisciplinary themes displayed at the 2014 Conference for Global Change.

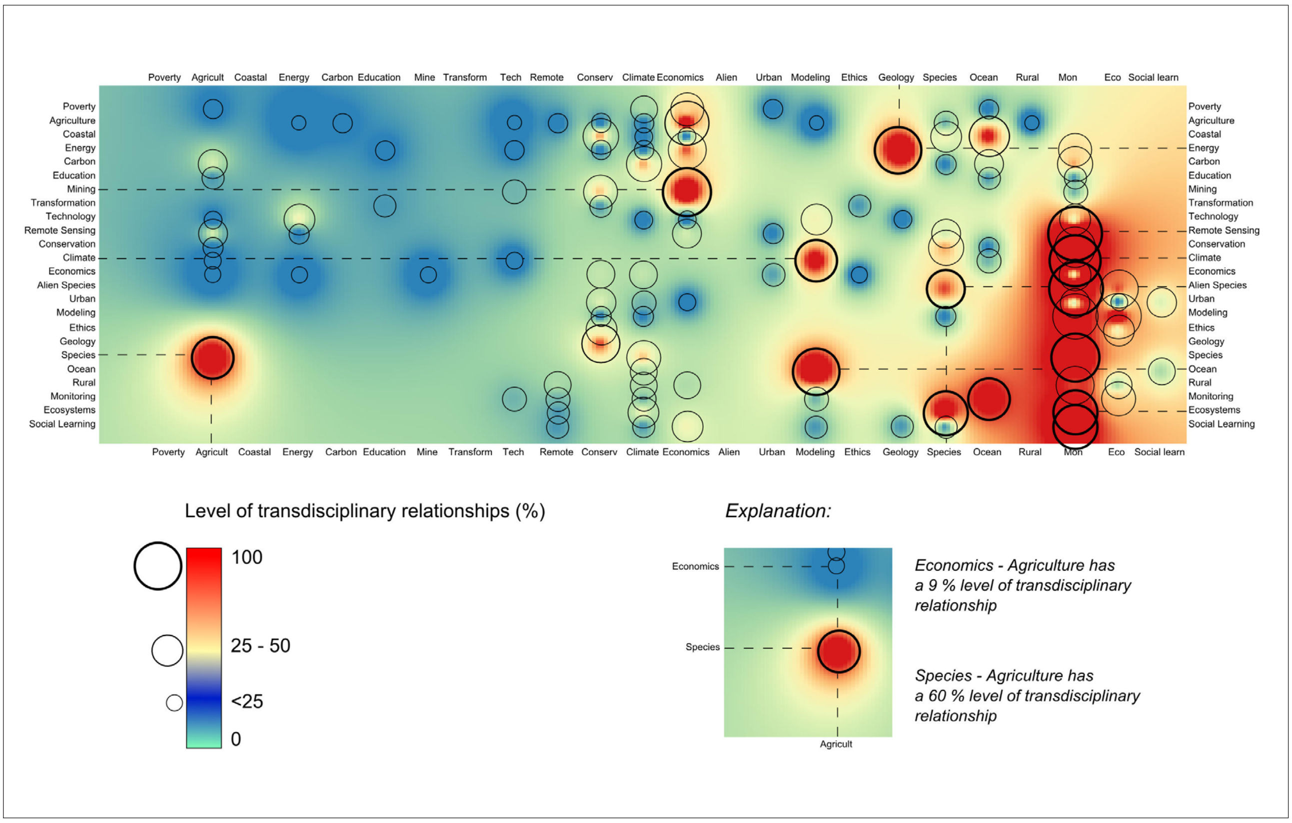

Figure 4: Overview of the degree of transdisciplinary within the Conference for Global Change, 2014. Circles indicate the intersection points between themes with a transdisciplinary nature; the colours represent the ratio (equated to a percentage within each theme) of the papers presented with transdisciplinary topics. Where no circle is shown, transdisciplinary relationships are absent.

The results also highlight many important non-linkages between research themes. Here we find a strong correlation between these non-linkages and some of the Grand Challenges that are unlikely to be met by the 2018 deadline:

1. Developing sustainable energy mix. South Africa struggles to maintain energy security and has failed to develop aggressive resolving policies related to energy security, which has resulted in negative economic consequences.[15-17] Failure to improve this area could reflect the <25% transdisciplinary link between Technology–Energy and Energy–Climate and a lack of policy development research being undertaken. It should also be noted that there is a very strong transdisciplinary link between Geology and Energy. This link largely stems from increasing shale gas research (e.g. http://www.karooshalegas.org/).

2. Human development and social dynamics. South Africa has seen advancement in social development[18]; however, inequality and youth unemployment continues to grow rapidly[19-21]. Is this a reflection of apparently poor links between Economics–Transformation/Education and Poverty/Rural Development, both of which have negligible shares of the total transdisciplinary research in the CGCG programme (Figure 3)? Education has been proven to be a vital aspect of any developing society.[22,23] Our analyses indicate that it needs to be better expressed within South African transdisciplinary research of the GCP.

3. Farmer to Pharma and the bio-economy. South Africa remains a net importer with negligible pharmaceutical or other beneficiation exports.[24] Interestingly, there is no dedicated Health theme in the CGCG programme, and <25% of research in Agriculture has a transdisciplinary link to Technology. Most transdisciplinary research within Agriculture is focused toward optimisation and increased productivity.

Today's strongly connected global process networks are highly interdependent systems that we do not understand well.[25] These systems are vulnerable to failure and can become unstable at all scales even when external shocks are absent. As the ever-increasing complexity of interactions in global networked earth and life systems becomes better understood, we may develop technologies to make the anthropogenic systems manageable so that fundamental redesign for future systems may become a reality. This aim is surely part of South Africa's plan to move towards a knowledge-based economy. But our results do not bode well for achieving this aim by 2018.

We are at the threshold of new transdisciplinary thinking about human and natural system complexity, and there is a long list of relevant questions that we must ask, and the relatively poor growth in transdisciplinarity over the last 5 years remains the most serious challenge to achieving Global Change Grand Challenge goals in South Africa. There is currently no way of establishing whether this poor growth may be related to 'top-down' initiatives or a lack of 'bottom-up' response. However, there is arguably a need for greater understanding at (under)graduate level in universities to better enable students from an early stage to grapple with the Grand Challenges of their global commons. A better understanding of the greater global needs of transdisciplinarity from an early stage in their careers may encourage them to extend their interconnectivity through the 'Internet of things' to shape their research direction early on.[26]

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