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Ecosystem service valuations of South Africa using a variety of land cover data sources and resolutions

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ABSTRACT

Valuation of the ecosystem services of South Africa is useful for many reasons, including: 1) providing an evidence based justification for investment in ecological infrastructure by both public and private entities, 2) informing resource allocation decisions with respect to the protection, restoration, and preservation of ecosystem functioning, and 3) enhancing public appreciation for the value of nature and our societal dependence upon natural capital. We present national assessments of ecosystem services values (ESV) based on a combination of approaches. We explore assessments that are derived from global datasets (~1 km) and finer resolution national datasets (~30 m). The global product is classified into 11 biomes in South Africa and the finer resolution data into 35 land cover classes. We apply ecosystem service values from the TEEB database to the respective datasets via benefits transfer methodology to both spatial resolutions. We estimate the change in ESV that has taken place in South Africa over 24 years using the 30 m data set. Our initial estimates of the total value of ecosystem services in South Africa from the global data set were $(US) 497 billion/year (1 km resolution 2014 data). The findings from the finer resolution data were $675 billion/year (1990 data), and $610 billion/year (2014 data). This, most recent (2014) estimate of total ESV is roughly 1.5 times larger than South Africa's GDP ($350 billion in 2014).

1. Introduction

There is an established consensus that human civilization, as currently practiced, is not sustainable. This consensus is not unanimous; however, it is overwhelming and the evidence on which it is based comes from a diverse community including ecologists, climate scientists, oceanographers, social scientists, geographers, economists, politicians, the broader public, and even Pope Francis. The economic valuation of ecosystem services is one component of the call for charting a path to a sustainable and desirable future. There is increasing recognition that a political economy focused on increasing Gross Domestic Product is overly narrow and fails to improve human well-being (Fioramonti, 2013). Human well-being actually results from an interaction of human, natural, social, and built capital (Costanza et al., 2014). This is a marked departure from traditional economic thinking. The latter concept sees the economy, not as an isolated loop of firms and households exchanging goods, services, capital, and labour; but as an economy within a society within the natural world (Daly and Farley, 2011?). The concept that the entire economy is smaller than, and contained by, the natural world is more scientifically accurate, imposes limits to growth constraints, and allows for the conceptualization of natural capital as having a larger and more fundamental role than built capital, with regard to the economy and overall human well-being. Estimates of the total value of the world's ecosystem services (the annual yield on natural capital) are roughly twice that of the world's market economy (Costanza et al., 1997; Costanza et al., 2014).

This study contrasts the value of the South African market economy with the value of ecosystem services generated by South Africa's natural capital. South Africa is the ninth largest country in Africa in terms of areal extent (~1.2 million km^2), and Africa's fifth most populous nation (~53 million persons). South Africa's economy (GDP ~$(US) 350 Billion 2014) is the second largest in Africa; however, South Africa's GDP per capita is only the seventh highest in Africa ($(US at PPP) 11,750). Nonetheless, poverty, unemployment, and inequality are persistent problems in the country.

Twelve million people live in poverty in South Africa (less than $(US) 1.25 / day). South Africa ranks in the world's top 10 for income inequality according to its GINI coefficient and has one of Africa's largest gaps between GDP per capita and the Human Development

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Index. Recognition of the value of natural capital provides a rationale for government programs that simultaneously reduce inequality, unemployment, and poverty, whilst providing stewardship, monitoring, and restoration of valuable natural capital.

The natural capital of South Africa represents ecological infrastructure that warrants increased investment for a range practical, rational, and ethical reasons. South Africa consists of over ten different climatic zones producing several unique ecosystems. South Africa is ranked sixth in the world's seventeen "megadiverse" countries that harbour the majority of the earth's species. Large swaths of natural habitat have been lost to urbanization, invasive species, agricultural expansion, and deforestation. Practical reasons for the restoration and preservation of these ecosystems include preventing soil erosion, extending the useful life of built infrastructure such as dams, maintaining a desirable tourist destination, and honouring national and international commitments (e.g. Convention on Biological Diversity, Kyoto Protocol, RAMSAR Convention, etc.). Economic reasons for these investments in stewardship include the win-win-win nature of addressing social problems such as inequality, unemployment, and poverty while simultaneously preserving and restoring a fundamental resource for economic advantage. These investments can be ethically justified through the commitment of current generations to make meaningful contributions to the well-being of future generations.

2. Data and methods

Our approach used land cover as a proxy for ecosystems and ecosystem services. Consequently, the fundamental data required for this valuation is land cover data and associated ecosystem service values. The following land cover datasets for South Africa were obtained:

1) An extraction of South Africa from a one kilometer resolution global land cover dataset (Costanza et al., 2014,
2) 2013–2014 South African Land cover dataset derived from 30 m resolution imagery (© GEOTERRAIMAGE-2014), and
3) 31,990 South African Land cover dataset derived from 30 m Landsat imagery (© GEOTERRAIMAGE-2014).

The 1990 dataset has 35 land cover classes. The 2013–2014 land cover dataset has a more detailed classification scheme with 72 land cover classes. These were aggregated to match the 35 land cover classes of the 1990 dataset to enable comparisons. The 2014 dataset of South Africa extracted from the 1 km resolution global data has only 7 terrestrial classes (Fig. 1A). The 1990 and the 2013–2014 South Africa land cover data product have finer spatial resolution (30 m spatial resolution) than the globally extracted product (1 km resolution) and include biomes that are specific to South Africa such as the 'fynbos' biome, unique to South Africa (Fig. 1B). The 30 m resolution data products were obtained courtesy of the South African Department of Environmental Affairs (DEA).

Mapping land cover is not exactly the same as mapping ecosystems or ecosystem services. However, a land cover map is a good starting point as it simplifies many of the complexities involved in mapping ecosystem services individually (Fig. 2). Land cover is a valid and useful, although a simplified method of understanding and valuing ecosystem services (Le Clec'h et al., 2016). While land cover may not be the ideal data source from which to approach all ecosystem service mapping tasks; it is probably the most systematic approach as it provides a big picture approach rather than piecemeal summations. It is for these reasons that there is an emerging consensus in the use of land cover maps as the primary spatial data structure on which to hang ecosystem and ecosystem service information (Costanza et al., 2014; Burkhard et al., 2009). Using land cover as a data structure or framework lends itself to linkage with ecosystem service datasets such as the ESV Database developed by The Economics of Ecosystems and Biodiversity (TEEB) (http://www.fsd.nl/esp/80763/5/0/50). TEEB Valuation Database is a searchable database with thousands of estimates of the monetary value of ecosystem services. Linking TEEB ecosystem service values from studies based on particular land cover types to a land cover map, is the simplest version of a benefits transfer model. This method is an oversimplification of ecosystem service valuation as it averages out spatial variation in the value of ecosystem services and ignores uncertainty in these measures. Progress is being made in the development of value transfer functions for global mapping (Schmidt et al., 2016). Ideally, a national assessment of ecosystem service value would use ecosystem service valuations and assessments that were derived solely from the country in question. Due to the limitation on available data the approach we present here used averaged global values and applies them to South Africa. We compare the results for South Africa extracted from a global dataset of 1 km spatial resolution, to a South African specific 30 m resolution dataset. Since biome specific ecosystem service values are not available for all 35 land cover classes of the 1990 and 2013–2014 dataset, we have reclassified the land cover classification into the seven biomes for which we have reliable total ecosystem service value data. This reclassification allowed the attribution of total economic value from TEEB ESV database. We used $ (US) per hectare from TEEB ESV Database (Costanza et al., 2014). The biomes are generic global values and are NOT specific to South Africa. The seven biomes used are Wetlands, Urban, Desert, Cropland, Grassland, Forest, and Water bodies. Using values from TEEB ESV database for each biome, $US / cell / year were determined for the relevant year (referred to as 1990 or 2014). The $US / cell / year values were also extracted from the 1 km global dataset (referred to as the ESV Base). South Africa is a diverse, yet unique environment with a number of unique biomes not found outside the country. In order to explore the effects of our simplification within the analysis on the value of South Africa's unique biomes (e.g. karoo and fynbos) we obtained delineations of the biomes of South Africa from the South African Department of Environmental Affairs. We used this polygon delineation data to determine the total values of ecosystem services for each biome. For example, the fynbos biome had a mix of grassland, forest, desert, and wetlands pixels within the polygon named fynbos.

3. Results

South Africa's terrestrial area was measured to be 122,400,000 ha. This is within 1% of other measures such as the World Bank. The classification of South Africa's land cover into seven primary biomes and assignation of values for our global dataset (Base), for the 1990 DEA 30 m dataset (2014) shows total values of $(US) 497 billion, $(US) 675 billion, and $(US) 610 billion respectively (Table 1).

For the 30 m resolution study, the DEA land cover datasets were assigned ecosystem service values associated with the aggregated global biomes (e.g. forest, desert, grassland, etc.). Using the more detailed dataset provided by DEA enabled a proxy valuation of the South Africa specific biomes, which included unique biomes such as Albany Thicket, Fynbos, etc. The total value of land covers for the South African biomes was thus determined and provided a measure of the value of each unique biome / hectare / year (Table 2). Azonal vegetation has a high value of $(US) 9099 per hectare per year, whereas desert has a low value of $(US) 726 per hectare per year. While "Desert" in the Base data has a value of zero, the "Desert biome" from the DEA biome dataset actually incorporates various other land covers that have values associated with them.

4. Discussion

There is a growing body of literature presenting a variety of arguments regarding the best approach to conducting ecosystem service valuation (Schröter et al., 2014). In the case of South Africa