WATER RESOURCE IMPLICATIONS OF A GREEN ECONOMY TRANSITION IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA: A MODELLING APPROACH REVIEW

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ABSTRACT

The Western Cape Province of South Africa has identified sustainable use of water resources as one of the critical needs to transform to a green economy. This paper aims to determine the role players in the water industry and an appropriate approach to model the potential effect that their actions might have. The drivers and enablers that affect water resources were found to be complex and interconnected. Further, from the review of a number of modelling techniques, system dynamics was subsequently identified as a technique that would be best suited for the case of water resources in the Western Cape Province. For the Province to transform to a green economy many changes that are long-term and multi-dimensional will need to take place; therefore the transition theory is also discussed in the context of multidimensional modelling. An extension of the study will be the development of the system dynamics model that will enable the involved parties to understand the expected water resource dynamics and identify potential leverage points to prevent future water shortages. Recommendations are made accordingly, for the research to ultimately lead to the improved management of sustainable growth in the African context.

Keywords: Water resources; Green economy; System dynamics; Western Cape; South Africa

INTRODUCTION

International urbanisation and industrial development are destroying the environment. Natural resources are continually diminishing as the economic welfare of the human race is growing. The awareness that natural resources is the cornerstone of life necessitated the need to regulate and alleviate the depletion thereof, and subsequently led to the concept of sustainable development.

Sustainable development became defined with the publication of Our Common Future in 1987 by the World Commissions on Environment and Development (WCED). It stipulated the importance of close interaction between economic, social and environmental development to meet the needs of the present without compromising the ability of future generations to do the same (Brundtland et al. 1987). In 1992 Agenda 21 was developed at the United Nations (UN) conference on environment and development. Agenda 21 initiated the implementation of policies and strategies to control development through integrating the three pillars of sustainability which is known from Our Common Future as economic, social and environmental.

Today many concepts have been developed to drive sustainable development and one of the more recent concepts is the transition to a green economy. The UNEP defines a green economy as an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities (UNEP 2011). The United Nations Environment Program (UNEP) has a Green Economy Initiative (GEI) which attempts to leverage significant green economy expertise within its global network of partners to build a global green economy. According to UNEP's definition, building a green economy involves analysing challenges and opportunities in specific sectors. Sectors that require investigation include agriculture, fisheries, forests, green buildings, industry, renewable energy, transport, waste management and water (UN 2011). Swilling et al (Forthcoming) however calls for a shift from a sector focus which tends to be narrow, to a "broad understanding of greening as a transitioning process of becoming more economically, socially and environmentally sustainable across the entire economy". The green economy principles are especially applicable to third world countries, which rely mainly on natural resources to drive the economy and sustain the populations' livelihood.

South Africans are heavily dependent on their vast natural resources. Economic growth, wealth creation and the livelihood of millions depend on the fruitful soils, forests, fisheries and other natural resources. As the young population of South Africa keeps growing, the demand for fresh water, food and health also grows and therefore the natural capital faces great pressure. In the light of this knowledge, South Africa has adopted numerous programmes and initiatives to support the transition to a green economy. One of these is the National Development Plan (NDP) which was established by the South African government in 2012 (National Planning Commission 2011)The NDP plans to eliminate poverty and reduce inequality by 2030. Furthermore the NDP states that the existing policies should be transformed into action and that each province in South Africa will require tailor made policies to suit their own complex needs.

In the Western Cape the transition to a green economy has its own complex requirements. The Western Cape is South Africa's major agricultural export area and also the country's most important international tourist attraction (Government 2013). Climate Change is expected to affect the Western Cape the most of all the provinces, with drought conditions that will increase in this already water-stressed region. The Western Cape Government has made an effort in the right direction by releasing a document called *Green is Smart* in 2013 (Government 2013). According to *Green is Smart*, the Western Cape strives to become the lowest carbon province and leading green economic hub of the African continent (Government 2013). They plan to do this by implementing smart-living and working, -mobility, -ecosystems, -agri-production and smart-enterprise (Government 2013). An integral part of *Green is Smart* is to promote and improve the sustainable use of water resources.

Internationally water is recognized as an important resource and will be essential when transforming to a green economy, particularly in water-scare areas such as the Western Cape. In the Western Cape large amounts of water are used for farmland irrigation, electricty generation plants and steel production. Western Cape households require a reliable supply of fresh water daily as it is fundamental to health, security, economy and ecology (Cape Town 2011).

The water resource implications when transforming the Western Cape to a green economy involve a number of non-linear and sophisticated interactions among various role players. Noting that the interactions between the role players is complex it essential to investigated the analytical modelling tools that can appropriately account these complexities. Consequently, the transition theory also needs to be investigated to fully comprehend the potential and extent of transforming the Western Cape to a green economy.

A discussion of the water resources in the Western Cape, an overview of Complex Systems, Transition Theory and possible modelling tools will follow. With this information an informed decision will be made regarding the modelling tool that will be utilised.

Water resources in the Western Cape

The preliminary investigation suggests that the rapid development of the Western Cape, as well as general water, energy, pollution, waste, transport and other inefficient uses of resources are leading to extensive environmental degradation. The government has published various documents that address these issues and establish long term plans which are intended to solve the most important problems. Water is at the centre of many of these plans.

Water is known as a key driver of economic and social development, therefore the demand for water will intensify as the population and the economy grow. This and the fact that the Western Cape is drying up (CSIR 2011) ensure that management and planning for water resources in the future becomes progressively more important. Water sources are divided between four major consumer groups namely; agricultural production, energy generation, industrial development and urban residential consumption (Von Bormann 2014). Not only will the water availability become an issue in the Western Cape but the water quality as well. This is why the trade-off between the water consumers is complex; both energy and agriculture are among the sectors who are responsible for the pollution of the water. In the agricultural sector, which consumes 60% of South Africa's water, inappropriate water management and irrigation technology is being used (Von Bormann 2014). Excessive use of fertilisers and pesticides are responsible for the contamination of groundwater sources.

The water shortage is also likely to be aggravated by the expected rising temperatures and consequently higher rates of evaporation and decreasing run-off (S Carter 2014). According to the CSIR scientists, South Africa is predicted to become generally drier (CSIR 2011). This argument is supported by Dr Celeste Barnardo-Viljoen (2013) who claims that rainfall in the Western Cape will decrease in the future. This will reduce surface runoff and slow down the recharge rate of ground water aquifers. Ultimately, this implies a reduced water yield from both surface and groundwater sources. Changes to coastal rainfall patterns could also lead to increased salt water intrusion into estuaries and coastal aquifers or raised groundwater tables near the coast (Statistics South Africa 2010).

To address the possibility of a drier Western Cape in the future, increased water conservation and demand management are necessary as well as alternative sources of water. Some alternative sources and key transitions listed below are identified in the Western Cape Infrastructure Framework (Palmer and Graham, 2013):

i. More strict water conservation and demand initiatives, particularly at municipal level.

ii. Develop available groundwater resources.

iii. Adopt the reuse of wastewater effluent more widely as standard practise.

iv. Adopt large scale desalination.

v. Expand and diversify agriculture to increase availability of surface water but reduce the water intensity of the sector, given the limited availability of water for irrigation.

The Western Cape Infrastructure framework (I. Palmer 2013) further states that little change to infrastructure is envisioned in sanitation infrastructure, potable water (drinkable water) service infrastructure and non-potable distribution infrastructure. However, it highlights that major shifts are required in water resource interventions. To bring about any changes significant capital investment is required. Desalination plants for example, require between 0.5 and 1.75 US dollar/m^3 (5.2 and 18.4 rand/m^3) when the plant's production capacity is above 20000m^3/day (Al-Karaghouli et al. 2013).

Furthermore, the Western Cape is divided into four Water Management Areas (WMA) as shown in Figure 1. The WMA's are known as:

i. Berg WMA

ii. Breede WMA

iii. Olifants/Doorn WMA

iv. Gouritz WMA

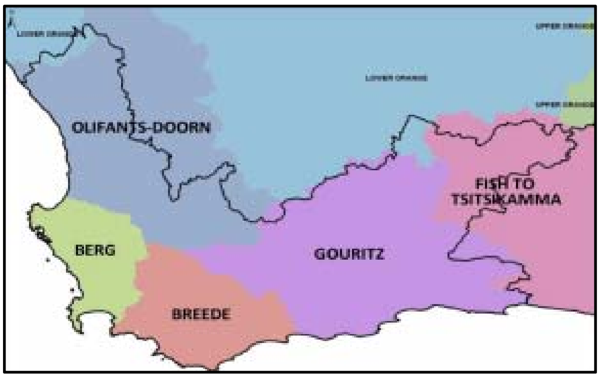

Figure 1: Water Management Areas in the Western Cape (Government 2011)

These four WMA's differ significantly in terms of surface area, groundwater resource availability, population size, landscape ecology, sensitivity for exploitation, rainfall patterns and temperature, just to name a few. Some of these WMA have integrated management plans while others need to be managed in a unique way. Water transfers between the WMA's are becoming more important as water demand and water availability in each WMA should managed in different ways.

Clearly water resources in the Western Cape is a complex system with numerous drivers and enablers, therefore Complex Systems and Systems Thinking will now be discussed to formulate a better understanding of how such a system operates.

Complex Systems and Systems Thinking

According to Glouberman (2002), a system can be understood as being simple, complicated and complex. Simple problems involve basic steps and terminology which can ensure a very high rate of success if the same steps are followed. Complicated problems are different, as its nature is not only related to the scale of the problem (simple system) but also to the issue of coordination and specialized expertise. Complicated problems are still similar and therefore once a success has been achieved a relatively high rate of success can be expected. In contrast complex systems are based on relationships, their properties of self-organisation, interconnectedness and evolution (Allen 2013).

A complex system is any system that involves a number of subsystems which in turn consist of interacting adaptive agents (Glouberman 2002). Therefore formulae have limited application on complex problems and experience or expertise may contribute but cannot assure success. Complex systems cannot be understood solely by simple or complicated approaches therefore complex systems theory should be utilized to represent real life more closely as it includes the study of the interactions of many parts of a system. The following characteristics of complex systems should be kept in mind; non-linearity, order/chaos dynamic, emergent properties, self-organization.

Sustainability and the transformation to a green economy were found to encompass the same characteristics of complex systems. Transforming the Western Cape into a green economy has been identified to involve many interrelated components that require analysis. Sustainable development is an open system that constantly evolves and unfolds. The interrelated components interact on a non-linear basis meaning that a small incitement may have a large or a small effect and on the contrary a big incitement may have a large or a small incitement. Furthermore, sustainability contains feedback loops. According to Rotmans and Loorbach (2009) these are all characteristics of a complex system.

Rammel et al. (2007) agree with Rotmans and Loorbach (2009) by stating that the management of natural resources should be able to deal with different spatial and social scales, complex uncertainty, multidimensional interactions, nested hierarchies and developing properties. To map the interactions between the different networks he drew his ideas from the Complex Adaptive System (CAS) theory, evolutionary theory and evolutionary economics. A CAS is “adaptive in the sense that they have the capacity to change and learn from experience” (Rotmans and Loorbach 2009). This is a characteristic of the transformation to a green economy if the behaviour of people (the catalyst) are analysed.

Having established that sustainable development and the transition to a green economy is a CAS, the way in which it operates needs to be understood for the purpose of this study. The CAS theory aims at improving the understanding of co-evolving, social-ecological systems and natural resource systems specifically. For natural resource management a CAS approach emphasises that these systems are known for the change in behaviour, rules and structure over time. This happens as the system adapts to their external environment like climate change or urbanisation (Rammel et al. 2007). Static and predictive approaches will not be helpful in the case of a CAS. Therefore an approach should be identified which can combine all the different components of this specific CAS known as the transition to a green economy.

A possible method to deal with complexity in a holistic manner is a systems thinking approach. Maani and Cavana (2007b) define systems thinking as a field of knowledge for understanding change and complexity through the study of dynamic cause and effect. The principles that are embodied by systems thinking is listed below (Maani and Cavana, 2007b):

i. Viewing the situation holistically or in other words the "big picture"
ii. Balancing short term and long term perspectives
iii. Recognising dynamic, complex, and interdependent nature of systems
iv. Taking measurable and non-measurable factors into account
v. Noting the presence of feedback loops
vi. Distinguishing between cause and symptom
vii. Using Either-Or thinking

Therefore, systems thinking is an approach that considers all possible influencing factors and establishes their interconnectedness and effects largely by means of modelling. The main contribution of a green economy has been identified as being the integration of several sectorial interventions in a comprehensible way.

Before modelling tools that takes systems thinking into account can be discussed, a better understanding of the Transition Theory is required.

Transition theory

Transition to a green economy can be considered as a CAS that is characterized by uncertainty, vague boundaries and multidimensional interactions, and is deeply rooted in our societal structures and institutions (Loorbach 2010). The only way to resolve and uproot these problematic characteristics of the transition to a green economy, is by the revision of both development processes and the institutions that have been built to handle them. A true transition is necessary to resolve persistent complex societal problem. Transition is described by Loorbach (2010) as:

> "A long term process of change during which a society or sub-system of society fundamentally changes."

To bring about a lasting successful transition, system innovation is required according to Loorbach & Rotmans (2009). The fundamental structure of the system and the relation among the participants will have to change. Innovation at the individual levels, in terms of product, process and project, will change within the system innovation. The innovations are required to be initiated from a preconceived goal of sustainable development.

Markard et al. (2012), claim in their article that a sustainable transition in a socio-technical system like water supply, involves "far reaching changes along different dimensions". As an example of the complexity of the transition to a green economy; a transportation system with the technology of the vehicle at its core, cannot function if the development of the road infrastructure, the fuel supply system, traffic rule services and user practices are not in full function. Markard et al. (2012) state that guidance and governance often play an important role in sustainable transformation. Four different conceptual approaches were identified. Here follow the four different approaches and a short description of each (Markard et al. 2012):

i. Socio-technical regime: Combines ideas and concepts from evolutionary economics and highlights that scientific knowledge, engineering practices and process technologies are socially embedded.

ii. Strategic Niche Management (SNM): Create and support niches to trigger off shifts.

iii. Transition Management: Combines work from technological transitions with insights from complex systems theory.

iv. Technological innovation systems (TIS): Concerned with the emergence of new technologies.

With the knowledge that has been gained throughout the literature study on sustainable development, a green economy, complex systems and the transition theory it is clear that a combination of Transition Management and System Innovation as described by to Loorbach & Rotmans (2009) will be the best conceptual approach to apply in this study.

Modelling tools

The literature study thus far has established what the transition to a green economy entails (Loorbach 2010, Glouberman 2002). With this knowledge further literature analysis was undertaken to determine which modelling tools are most appropriate to better understand and analyse the potential for green economy transition. The main contribution of a green economy was identified as being the integration of several sectorial interventions in a comprehensible way. The modelling tools that attempt to integrate interventions were identified and are discussed briefly, namely (Bassi 2014):

i. Econometrics

ii. Optimisation

iii. Simulation: System Dynamics

Econometrics runs a statistical analysis of historical data to find the relation between selected variables (Bassi 2014). The modelling approach involves three stages namely specification, estimation and forecasting, and applies statistical methods and mathematics to economic theory, throughout these stages. This tool provides quantitative estimates, predictions and forecasts. The limitations lies in the data used as all economic relationships are estimated using data generated by a complex system which is characterized by variables that are unpredictable (Ouliarism 2011). The data used is incomplete and imperfect and this leads to the rising of concerns with the validation of the projections.

Optimisation is a tool that leads to models that provide information on how to make the best of a situation. Three main inputs are required to optimise a situation, they are the objectives, areas of intervention and the restrictions (Bassi 2014). When taking sustainable development into account optimisation has difficulty to provide a forecast. The reason for this is that optimisation models requires the correct objective function definition, extensive use of linearity and has limited representation of feedback loops (Bassi 2014).

Simulation has three major approaches, namely discrete event modelling, agent based simulation and system dynamics (Bassi 2014; Doodley 2005). According to Doodley (2005), the conditions for use in each of the simulation approaches are as follows:

i. Discrete event modelling: A system described by variable and events that trigger change in those variables.

ii. Agent based simulation: A system described by agents that react to one another and the environment.

iii. System Dynamics: A system described by variables that cause change in each other over time.

When dealing with the issues of green economy and broadly, sustainable development, it becomes essential to "describe variables that cause change in each other over time", which is the condition for use of system dynamics. Furthermore, system dynamics offers a model that resembles reality structurally, so one can review it for usefulness and consistency. It offers a way to see the consequences of that simplification through simulation, so one can test mental model assumptions and dynamic hypotheses (Williams 2005). Further, system dynamics account for feedback loops and it is particularly well suited to modelling social problems that are related to sustainability challenges (Sterman 2001). Variables are arranged into feedback loops to form the important structure of the system. Since the way that structure behaves over time is easily simulated, system dynamics can give powerful insights (Sterman 2001).

Conclusion

The key criteria that were used to choose an appropriate approach included that it should:

i. Be able to endogenously represent key variables

ii. Be comprehensive

iii. Properly represent dynamic complexity

iv. Be transparent

These four criteria are best taken into account by system dynamics when compared to econometrics and optimization. Furthermore, econometrics was dismissed as the data that is used for this modelling tool is generated by a complex system of which the variables are unpredictable. Therefore the data used is incomplete and imperfect and consequently the projections are hard to validate. It is important to be able to validate the projections made to convince and encourage people to adopt a "green" way of living. The most important limit of optimisation is that it supports linearity rather than feedback loops. Feedback loops are an important factor when considering the transition to a green economy, therefore optimisation was dismissed as well.

There is no perfect method for forecasting a given real-life situation, especially the transition to a green economy as it involves a complex system. However, system dynamics was chosen as best modelling approach for the purpose of this paper.

METHOD

System Dynamics is a method to define, model, simulate and analyse 'real-world' issues dynamically (Pruyt 2013). It provides an outline for qualitative description, investigation and analyses of systemic problems in terms of processes, rules, information and boundaries (Mirchi et al. 2012). This enables quantitative computer simulation modelling and analyses to assist in understanding the underlying reasons for observed behaviours (Sterman 2001).

System Dynamics is particularly good at capturing the dynamics of a feedback system. Feedback systems have a closed loop structure that brings results from past actions of the system back to control and affect future action. Therefore feedback systems are influenced by their own past behaviour (Mirchi et al. 2012).

Generally, system dynamics modelling involves five major steps, namely, problem identification, conceptualisation, model building, model testing and policy analysis (Sterman 2001; Maani and Cavana 2007). These steps are iterative and involve both qualitative and quantitative modelling. Qualitative modelling basically entails problem identification and conceptualisation, and the issue investigated is mapped out using either causal loop diagrams (CLD) or influence diagrams.

CLD illustrate the relevant parts of a system using variables, the links between the variables are arrows pointing in the direction of influence, (Maani and Cavana 2007a), the signs "+" or "–" are used to indicate whether the influence is positive or negative while the signs "R" and "B" are used to denote whether a feedback loop is reinforcing or balancing respectively. Figure 2 is the population CLD and illustrates the most basic components of CLD.

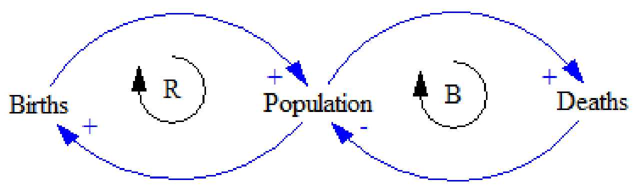

Figure 2: Population CLD

A reinforcing loop is a positive feedback system. It can represent growing or declining actions (Maani and Cavana 2007a). The reinforcing loop shown in

Figure *2* is an example of a growing action where the more the population the more births will take place and the more births there are the more people there will be.

A balancing loop is a negative or counteracting feedback loop and seeks stability (Maani and Cavana 2007a). The balancing loop in

Figure *2* follows the logic that more population will cause more deaths and the more deaths there is the less the population will be. Other examples of such balancing mechanisms are our bodies and the ecological systems.

Delays are a characteristic in most systems. Different types of systems experience different types of delays (Mirchi et al. 2012). For example, in system dynamics delays refer to the time lapse between a cause and its effects (Mirchi et al. 2012). These delays can either be information delays or material delay. In a CLD, the notation "||" on the arrow is used to represent a delay.

Figure *3* thus demonstrates a material delay in a water demand system, where, for the available water stock to become potable water because it is required to be treated, hence the time delay.

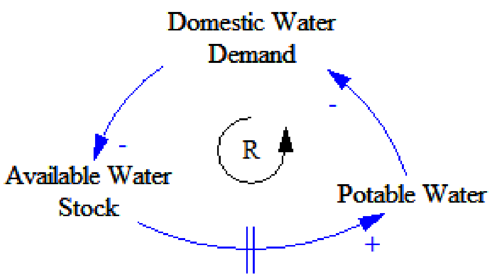

Figure 3: Reinforcing loop with a Delay

In the quantitative modelling in system dynamics, this entails the three other phases of modelling process. Quantitative modelling provides insight into the actual behaviour of the system over time, and it makes use of stock and flow diagrams. A stock and flow diagram is usually constructed from a CLD and is generally more detailed than the CLD.

This paper focussed on the qualitative part of system dynamics and utilised CLD to conceptualise the water resources in the Western Cape and its implications within the context of green economy transitioning. The quantitative part of system dynamics using stock and flow diagram is currently work in progress. The CLD describing the different parts of the water resources system in the Western Cape is discussed is section 4.

PROVISIONAL OUTCOMES

The CLD for the water resources in the Western Cape was developed by using Vensim Software. The main feedback loops are described in separate CLD's which are ultimately linked together to show the overall Water Resource CLD.

Water resource investment CLD

Figure 4 shows the water investment CLD which consist of one balancing loop (B1) and one reinforcing loop (R1). The balancing loop B1 indicates that if the available water stock is not sufficient to provide all the sectors and people with water, there will be more urgency to save water and the green economy water budget will be increased. An increase in the budget will result in an increase in water management investment. An increase in water management investment will ensure that more water saving initiatives are invested in and ultimately the available water stock will increase. Water saving initiatives include:

- Water transfers in;
- Leakage Repair;
- Pressure Management;
- User Education;
- Reuse of waste water;
- Large scale desalination;
- Ground water protection;
- Clearing alien vegetation; and

Dam construction

On the other hand, the reinforcing feedback loop R1, shares some variables with B1 but has an additional variable GDP (Gross Domestic Product). With R1, the more the available water stock to support the economic activities such as agriculture, industry and services, the more the GDP would be. The more GDP an economy has implies that there is potential to allocate more budget for green economy activities in water. The more the budget allocated, the more the water management investment, which will then result in an increase in water savings initiatives and ultimately, an increase in available water stock.

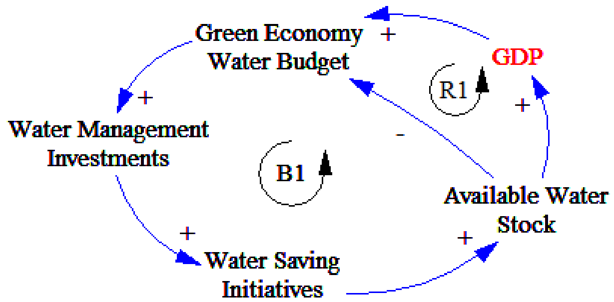

Figure 4: Water resource investment CLD

Raw water supply CLD

Figure 5 shows the raw water supply CLD which consists of one reinforcing loop, R2. The more the available water stock, the more raw water outflow there will be. This raw water outflow is then distributed among numerous water usages namely:

Irrigation;

Mining and bulk industries;

Electricity generation;

Afforestation;

Sewage;

Recreational usage;

Land usage; and

Infrastructure

The more the water that flows from these usages, the more waste water there will be. Waste water goes through a treatment process before it becomes available stock. Hence the more the waste water that is produced and treated, the more the available stock of water. Also, the more the waste water, the more the available water stock.

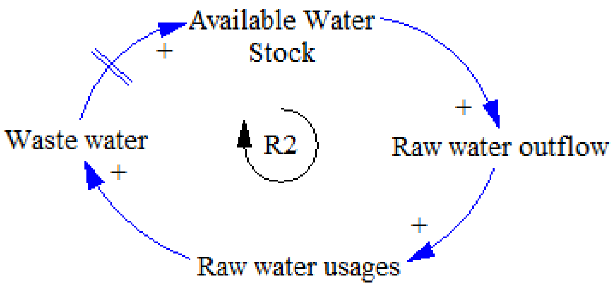

Figure 5: Raw water supply CLD

Raw water demand CLD

Figure 6 describes the raw water demand CLD which consists of 2 balancing loops and 2 reinforcing loops. Population CLD that was illustrated in

Figure *2* consists of one reinforcing loop (R4) and one balancing loop (B2). The more the population, the more the urban/rural domestic consumption. This in turn influences the amount of potable water in that, the more this demand, the less the potable water available and the less the potable water available, the less the urban/ rural domestic consumption. Increase in urban/rural domestic consumption will result in an increase in the need for available water stock. The more the available water stock the more the raw water flows. The raw water or untreated water should be treated before it can be classified as potable water, therefore there would be a delay. The more the raw water outflow the more potable water would be available. It can then be argued that the more the potable water stock the more the urban and rural consumption will be. This creates a reinforcing loop.

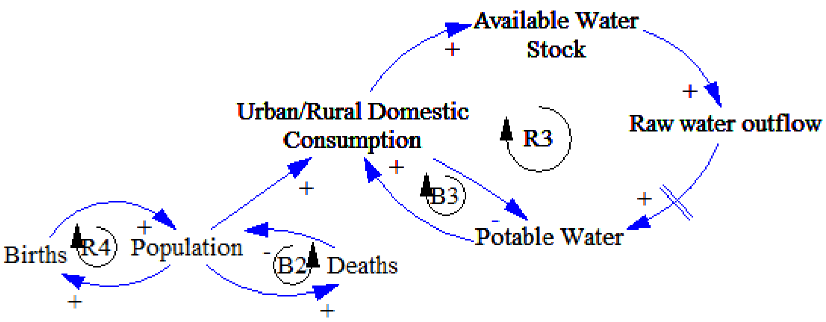

Figure 6: Raw water demand CLD

Raw water transfers CLD

Figure 7 shows the raw water transfers CLD which describes outflow water transfers out of the Western Cape. It consists of one balancing loop, B4. It is different from the other outflows as the water does not become wastewater. The more water that is transferred out of the province the less the available water stock would be, and the less the available water stock, the less the raw water outflow within the Western Cape Province.

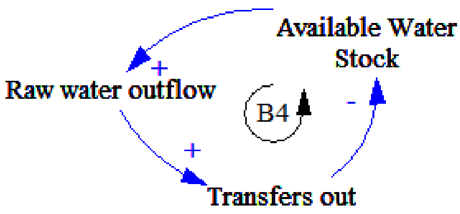

Figure 7: Raw water transfer CLD

Natural water cycle CLD

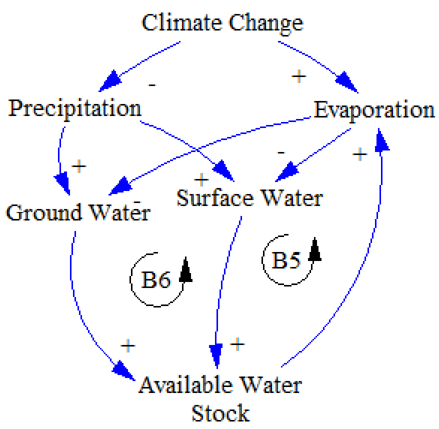

Figure ***8*** shows the natural water cycle CLD, which consists of two balancing loops, B5 and B6. The more available water stock the more evaporation will take place. Increased evaporation decreases the amount of surface and ground water. With less surface (B5 loop) and ground water (B6 loop), this results in less available water stock. Climate change is an exogenous variable and it is assumed that the Western Cape will become hotter as a result thereof, therefore it will increase evaporation and decrease precipitation. In turn, precipitation increases so will surface water as well as ground water.

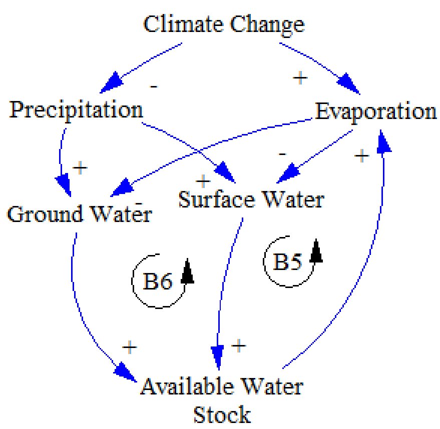

Figure 8: Natural water cycle CLD

Water resource CLD

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The CLD's described above were combined to show overall Water Resource CLD in

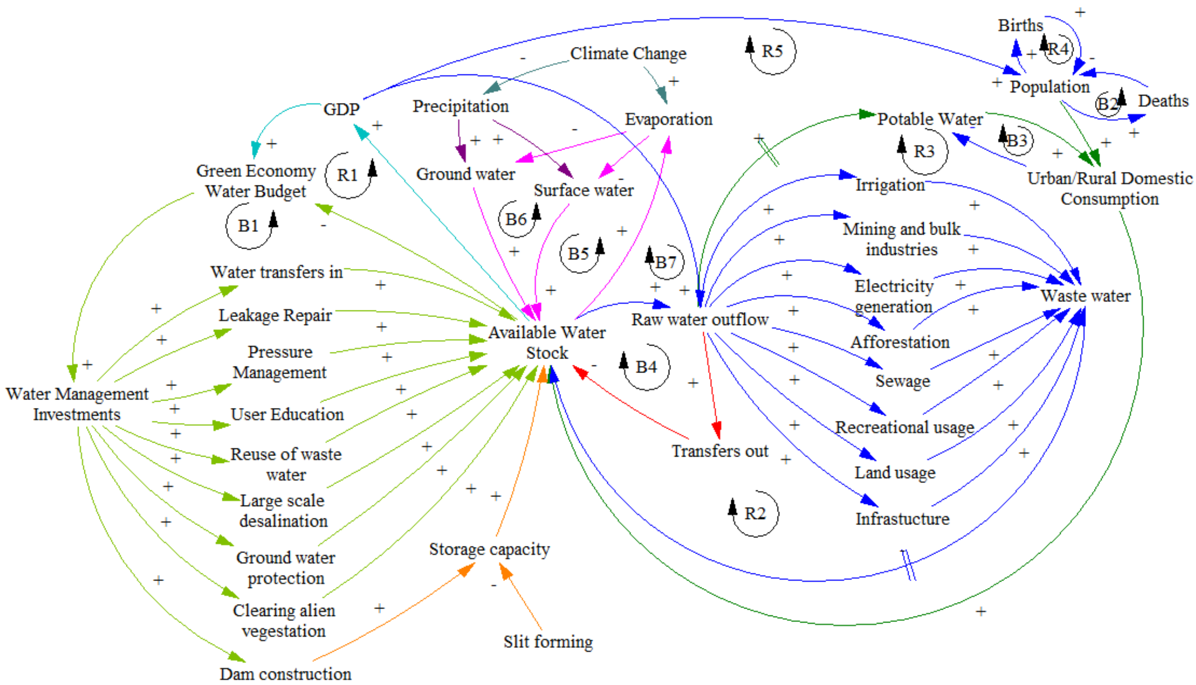

Figure *9*. Feedback loops that should be noted is between the GDP and the population (R5) as well as with the raw water outflow (B7). In B7, the higher the GDP the more water would be required to keep up with the development that will take place. Furthermore, in R5 the population will increase as more immigration into the province takes place and people will have more resources and therefor bigger families. The water saving initiative called dam construction, increases the storage capacity of the Western Cape but an exogenous variable called slit formation also decreases the storage capacity.

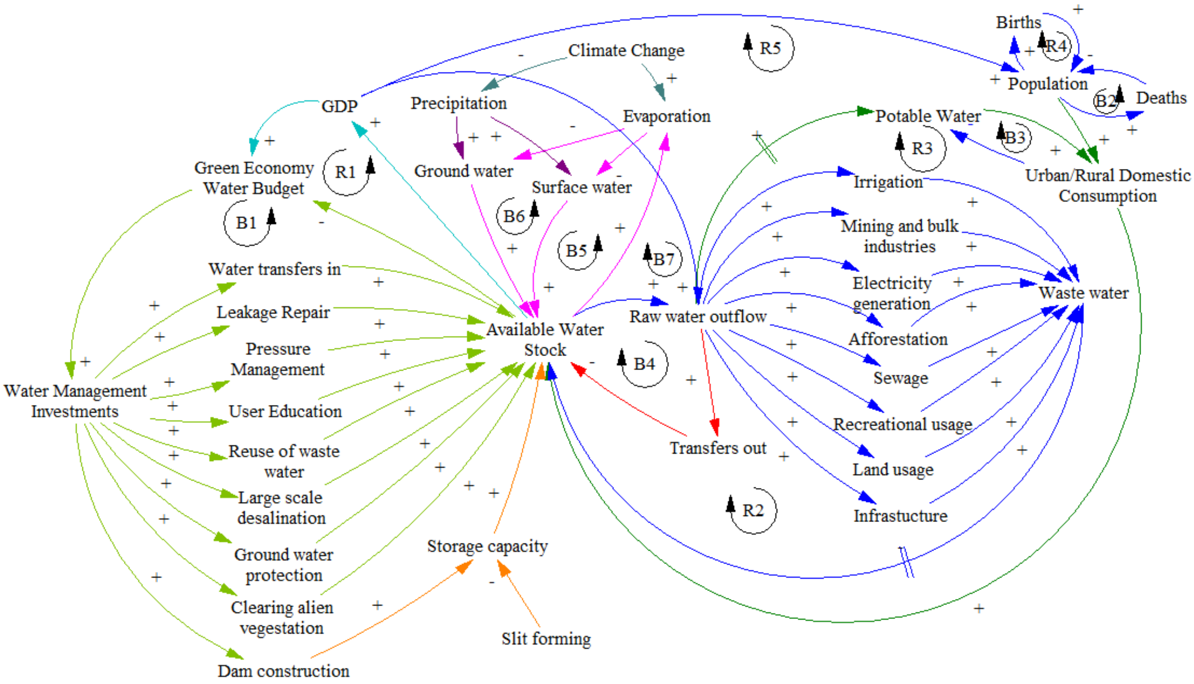

Figure 9: Water Resource CLD

CONCLUSION

For the Western Cape province of South Africa to transition to a green economy, sustainable use of water resources is identified as a critical necessity. This paper aimed to conceptualize the factors that influence the transition to a green economy in the Western Cape regarding the water resources and provides a modelling technique that will best suit this industry.

Many different role-players in this industry interact on a non-linear basis which makes it difficult to know what consequences different actions will have. Therefore, the water resource industry was found to be a system with complex interconnections and dependencies. A number of modelling techniques namely; econometrics, optimisation and system dynamics were studied to establish which technique would be best suited for the case of water resources in the Western Cape. System dynamics was identified as an approach to this complex system.

Even though this real-life situation is impossible to model to perfection it was concluded that System Dynamics modelling will best represent the dynamics complexity that are inherent in green economy transitioning. System Dynamics characteristics, such as its stock flows and casual loop utilization as well as its ability to model complex real life situations on a relative low level of complexity proved it to be the best tool.

The paper focussed on the qualitative part of system dynamics where a CLD of the water resources in the Western Cape was developed. This consisted of five causal loop diagrams namely: water resource investment CLD, raw water supply CLD, raw water demand CLD, raw water transfers CLD, natural water cycle CLD.

Recommendations and way forward

The next step of this study is the development of a quantitative model using stock and flow diagrams, which is currently underway. Different scenarios will be tested in this model regarding the investments into water management initiatives which will contribute to the sustainability of water resources in the Western Cape. It is expected that the outcomes of the system dynamics modelling will inform on the implications of green economy investments on social, economic and environmental targets of the province.

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