Polycentricity, Pluralism and Citizen Science: A Nexus Approach to Water Resources Management

Report to the
Water Research Commission

by

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Executive Summary

Typical for South Africa in general where 74% of the rural population are completely dependent on groundwater, groundwater is the dominant water supplier in the Hout Catchment, Limpopo. As the management guru Peter Drucker claimed you can't manage what you can't monitor and thus monitoring systems are essential, especially as surface water resources are exploited to their full capacity and the dependency on groundwater resources has increased and continues to increase across the country. Our current Water Research Commission (WRC) project entitled 'Polycentricity, pluralism and citizen science: a nexus approach to water resources management (POPLUC),' draws on early lessons from the first project of its kind in South Africa on citizen science (CS) for groundwater monitoring entitled Enhanced Sustainable Groundwater Use in South Africa (ESGUSA). Here we developed a CS approach to address the hydrological data void in municipal and governmental databases and empower stakeholders in their local management of water resources. A WRC project (WRC 2020/2021-00085), entitled 'Citizen science for groundwater monitoring in the Limpopo (CISMOL)' built on the ESGUSA work and precedes POPLUC.

Through CISMOL citizens were trained on the use of cost effective and appropriate technology to obtain data on groundwater and rainfall. A verification and validation system to monitor and evaluate data for CS was developed. The idea of a living laboratory was applied which is an approach to research on real-life challenges in collaboration with scientific and public actors, establishing a community of practice, to ensure that identified aspects of monitoring are being applied. We were able to assert that that data collected by the volunteers is no less reliable than data collected by 'scientists'.

Hand in hand with the monitoring of groundwater levels and rainfall we tap into the 'softer' human side which is to do with feelings and emotional well-being. How do the volunteers feel about the work they are doing? Do they have a sense of pride? A sense of belonging to a broader catchment area? Do they have a sense of upstream/downstream flows and if not, what type of information is needed to ground them better in the catchment as a whole and to boost water literacy? We worked closely with the Department of Water and Sanitation (DWS) and the Department of Agriculture, Land Reform and Rural Development (DALRRD) as well as the research community and our advisory committee (Reference Group). In CISMOL we applied participatory action research as a mode of systematic inquiry, an action research methodology

that focuses on social change. This is a qualitative research methodology that fosters collaboration among participants and researchers.

Following on from CISMOL we took up the challenge of creating a more robust theoretical frame to apply to citizen science groundwater monitoring efforts. Building on our previous experience, POPLUC has given us the confidence that we have a theoretical frame and a very practical protocol for how to implement a citizen science project for monitoring groundwater. We are confident that we can now upscale and roll out the protocol elsewhere in the country and that we are able also to include water quality monitoring in the future.

We present the report in seven parts. The first part covers the geographical, environmental and institutional context of the project. In part two we present 'big players' who are involved in water monitoring. As over 18 million rural people (about 40% of the national population) live under the jurisdiction of traditional leaders we draw attention to tribal authorities. In part three, we focus on the rules and regulations for monitoring groundwater. Part four presents the concept of a nexus, citizen science, pluralism and polycentricity. Part five pulls the threads together through a POPLUC model in the form of a storyboard. A scientometric analysis using the keywords citizen science, pluralism and polycentricity is presented in part six. The scientometric analysis confirms that our study is unique in combining the three concepts. It thus makes a contribution not only to the body of knowledge around these concepts but brings for the first time these concepts into the field of water resources management in general and groundwater in particular.

The nexus approach to environmental resources management considers interrelatedness and interdependencies of environmental resources. In our conceptual frame the first idea we present is citizen science. Citizen science over the past decades, is part of a new struggle for the production of knowledge – generating expertise, fostering scientific literacy, and enhancing learning. Literacy about groundwater is empowering and in encouraging citizen participation in data collection, analysis and interpretation, we recognise the emancipatory and transformative possibilities of CS. CS holds the potential for developing new ways to collectively solve big problems and to fundamentally change the relationship between science and society. The second nexus concept is pluralism. The Global Centre for Pluralism defines this concept as a set of intentions and practices that seek to institutionalize difference and respect for diversity. Values are plural, conflicting and incommensurable – they are incomparable and cannot be seamlessly exchanged or collapsed into one another. Pluralism holds that social diversity and the disagreement that grows from it are unending. The attempt to permanently quench

difference misrepresents and distorts human experience. Feminist philosophers have played an important historical role in undoing the notion that humans exist with singular universal politics, ethics, epistemology, etc. Polycentricity is the third concept in our nexus. Polycentric systems are complex adaptive systems without a central authority controlling the processes and structures of the system. All centres retain significant autonomy from any other centre. Cases of polycentric governance are rife with jurisdictions whose connections are either formally absent or ambiguous and confusing.

The idea of yarning binds polycentricity, pluralism and citizen science more tightly together. All too often researchers refer to 'wicked' problems and the ways these are linked to the notion of complexity. Yet, in so doing their theoretical frames tend to be rigid. We show in the report the usefulness of the idea of yarning and meshwork picking up on what we believe to be a more accurate picture of the socio-economic-political landscape we find in our study area. This landscape is one of entanglement, fragility, puzzles and disconnects that are integral to the reality on the ground when dealing with citizen science and groundwater monitoring.

The idea of yarning – from the verb 'to yarn' means to tell a story – but also to twist fibre to give it strength and durability. Meshwork and yarning reflect the entanglement of individuals. When we think of the complex institutional, social, political and environmental landscape that we present in part one and two of the report, it is helpful to keep in mind images of knotting, yarning and entanglement. The human world is entangled not only with people but with the natural environment as well as the materiality of things such as dip meters, boreholes, etc. and with the laws and regulations – be these customary (through tribal authorities) or statutory. Furthermore, there are small worlds (a household next to a borehole) that collide with bigger worlds and different layers of decision making that often pass each other like ships in the night. A volunteer gathering data might be completely disconnected from the laws that govern the resource and vice versa, those who make the laws and regulations might have little understanding of very practical efforts on the ground to gather data and address a hydrological void.

We develop a POPLUC model that can be applied within the Hout and beyond. In the spirit of this study our model is in the form of a storyboard. There is a visual or visceral aspect to science that is not easily portrayed in academic writing and the storyboard gets closer to seizing this aspect. As we take science into the public arena we emphasise tensions, disruptions, connections and disconnections. In so doing we move away from the impulse to erase doubt or error as we

acknowledge and make visible the unknown, the confused and the contradictory aspects of polycentricity, pluralism and citizen science. Similarly, where the ghosts of apartheid built walls between commercial (white) and small scale (black) farmers, there are now new pathways and 'threads' being strengthened and given durability through the activities in the project. People who were distanced from one another are now connected in new ways. The ideas of polycentricity, pluralism and CS are not abstract theoretical notions but real lived experiences. In bringing together the concepts of citizen science, pluralism and polycentricity through a feminist lens, we contribute to a fresh theoretical frame through which to examine groundwater monitoring and citizen science.

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We would like first of all to thank the Water Research Commission for believing in the importance of citizen science for groundwater monitoring. In particular John Dini for his valuable insights and support to us on this journey. Thank you to all members of the Reference Group for their time and expert input. The project would not have been possible without the citizen scientists themselves and their efforts in providing regular, valid and verifiable data. A particular thank you to Dr Muchingami who continued the fieldwork taking personal risks during COVID lockdown to ensure that data was being verified and validated. Thank you to DWS for their ongoing support. A special thank you to the research team for their tireless efforts and contributions.

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Acronyms

ADBG	African Development Bank Group
AFASA	African Farmers Association
AU	African Union
BGCMA	Breede-Gouritz Catchment Management Agency
CDM	Capricorn District Municipality
CISMOL	Citizen Science Groundwater Monitoring in the Limpopo
CMA	Catchment Management Agency
CS	Citizen Science
CSA	Citizen Science Alliance
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
DMRE	Department of Mineral Resources and Energy
DSI	Department of Science and Innovation
DST	Department of Science and Technology
DTLF	District Traditional Leaders Forum
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical conductivity
ECSA	European Citizen Science Association
ESGUSA	Enhanced Sustainable Groundwater Use in South Africa
EU	European Union
GRAM	Groundwater Resource Assessment and Monitoring
GWP-SA	Global Water Partnership Southern Africa
HDI	Historically disadvantaged individual
IB	Irrigation Board
IGD	Institute for Groundwater Studies
IGRAC	International Groundwater Resources Assessment Centre
IWRM	Integrated Water Resource Management
MDG	Millennium Development Goal
NAFU	National African Farmers Union
NEPAD	New Partnership for African Development
NGA	National Groundwater Archive

NGO	Non-Governmental Organisation
NGS	National Groundwater Strategy
NWA	National Water Act
PMG	Parliamentary Monitoring Group
POPLUC	Polycentricity, pluralism and citizen science
PTO	Permission to Occupy
RSA	Republic of South Africa
SADC	Southern African Development Community
SADC-GMI	The Southern African Development Community Groundwater Management Institute
SANS	South African National Standard
SAWINET	Southern African Water Information Network
SDG	Sustainable Development Goals
SNA	Social Network Analysis
SONYC	Sounds of New York City
TCTA	Trans-Caledon Tunnel Authority
TDS	Total Dissolved Solids
UPGRO	Unlocking Africa's Groundwater Potential
WMA	Water Management Area
WRC	Water Research Commission
WRM	Water Resources Management
WSA	Water Services Authority
WSP	Water Services Provider
WUA	Water User Association

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Part One: Background and context

1.1 Introduction

As our project draws to an end, we want to make sure that our main ideas are brought to the forecourt and don't, through lengthy text in this report, get lost in translation. As such, we use visual aids to capture core ideas and provide a 'breathing' space by using 'sky blue' text to ease our messages across to the reader. The idea of yarning – which is introduced in the section on pluralism, is central to the report which is on the one hand telling a story and, on the other, taking the reader on a journey of entanglement, enmeshment and yarning. We structure the report in seven parts. The first presents a canvas – an anchor onto which our narrative is pinned and this is the geographical, environmental and institutional context of the project. Here we present the project background, its geographical, social and political context. In part two we present 'big players' and go onto the next section, part three, to focus on how water is monitored – what the rules and regulations are. Part four is conceptual and takes the reader through the idea of a nexus, citizen science, pluralism and then polycentricity. Here we also present actor network theory and argue for thinking beyond this theoretical frame. Part five pulls the threads together presenting a traditional model. The model brings together the lexicon of POPLUC in a simplified way that makes it easily accessible but then offers a visual rendering in the form of a storyboard which is dynamic and alive – giving breathing space to the ideas put forward in this study. Part six is a brief overview of our scientometric analysis using the keywords citizen science, pluralism and polycentricity. We end with the final part, seven, which is our conclusion. In our conclusion we now know that this current project is a first of its kind that brings polycentricity, pluralism and citizen science together, thus making a unique contribution to the world of water and also to the science that sits behind our concepts. We hope to show in the report, how entangled too the concepts are and how yarning binds disparate ideas and encourages a package that is not cast in stone but that is forever on the move. We invite the reader to embark on this puzzling, surprising and complex journey with us.

1.1 A canvas: geographical, socio-political, environmental and institutional profile

1.1.1 Why groundwater?

Various public organisations and departments are involved in the administration, management and protection of water resources and implementing policies and legislation (Ostrom, 1996).

Groundwater is a precious water resource that occurs underneath the ground surface located in spaces between soil particles and in the fractures of gravel, sand and rocks. Due to surface water resources being exploited to their full capacity, groundwater resources have a vital role of water supply to many countries across the globe. Therefore, the protection, conservation and management of this resource has become a priority for governments.

In the Republic of South Africa (RSA), there are laws, acts and policies that have been formulated by different government departments to ensure sustainable use and management of groundwater resources. There is still work that has to be done pertaining to the protection, management and development of groundwater resources in the country. The formulated laws and policies need to be implemented in every area of the country and stricter consequences should be enforced especially for mining and industrial users – negative impacts on groundwater resources affect surface water resources as well. In a country experiencing arid conditions and water shortages, groundwater resources need to be protected by all means to ensure that future generations also benefit from these resources.

Groundwater is an increasingly important source of water supply to agriculture, households and industry. Groundwater is generally well protected against pollution, can be exploited anywhere depending on the local conditions and has a year-round availability. With population growth and increasing climate variability, groundwater also plays an increasingly important role in the RSA to enhance water and food security.

Our present understanding of the threats to groundwater posed by climate change are far from clear, especially in light of the complex interactions between demographic and land use changes and the detailed unfolding of changes in key weather variables such as temperature and precipitation. That local water balances are already changing and that such change is set to continue, is not controversial. However the precise shape of those changes locally and the implications for groundwater's continuing ability to buffer seasonal and multi-year dry periods are less well understood.

1.1.2 Project context

This current Water Research Commission (WRC) project entitled 'Polycentricity, pluralism and citizen science: a nexus approach to water resources management (POPLUC),' draws on early lessons from the first project of its kind in the RSA on citizen science (CS) for groundwater monitoring. The objective of this former project, entitled Enhanced Sustainable Groundwater Use

in South Africa (ESGUSA) was to develop and assess a CS approach that contributes observations to support an understanding of catchment hydrogeology and equip local stakeholders to better participate in water resources management (WRM). In particular, it addressed the hydrological data void in municipal and governmental databases on hydrogeology, supporting on-going interactive work on hydrological modelling, and empowering stakeholders in their local management of water resources. A second WRC project (WRC 2020/2021-00085), entitled 'Citizen science for groundwater monitoring in the Limpopo (CISMOL)' built on the ESGUSA work and precedes POPLUC.[1]

The geographical boundaries of our case study are defined by the Hout Catchment, Limpopo Province, located north-west of the provincial capital city Polokwane. A semi-arid climate is prevalent in the area with an annual long term mean precipitation of 407 mm/year. The area is well known for its agricultural (in particular potato production) and tourism activities. Centre pivot is the main irrigation system across the catchment. The Hout catchment has an area of 2.480 km^2 and contains one larger dam that is used for domestic water supply (see map of catchment below).

[1] WRC Report no. 3017/1/22 ISBN 978-0-6392-0146-7

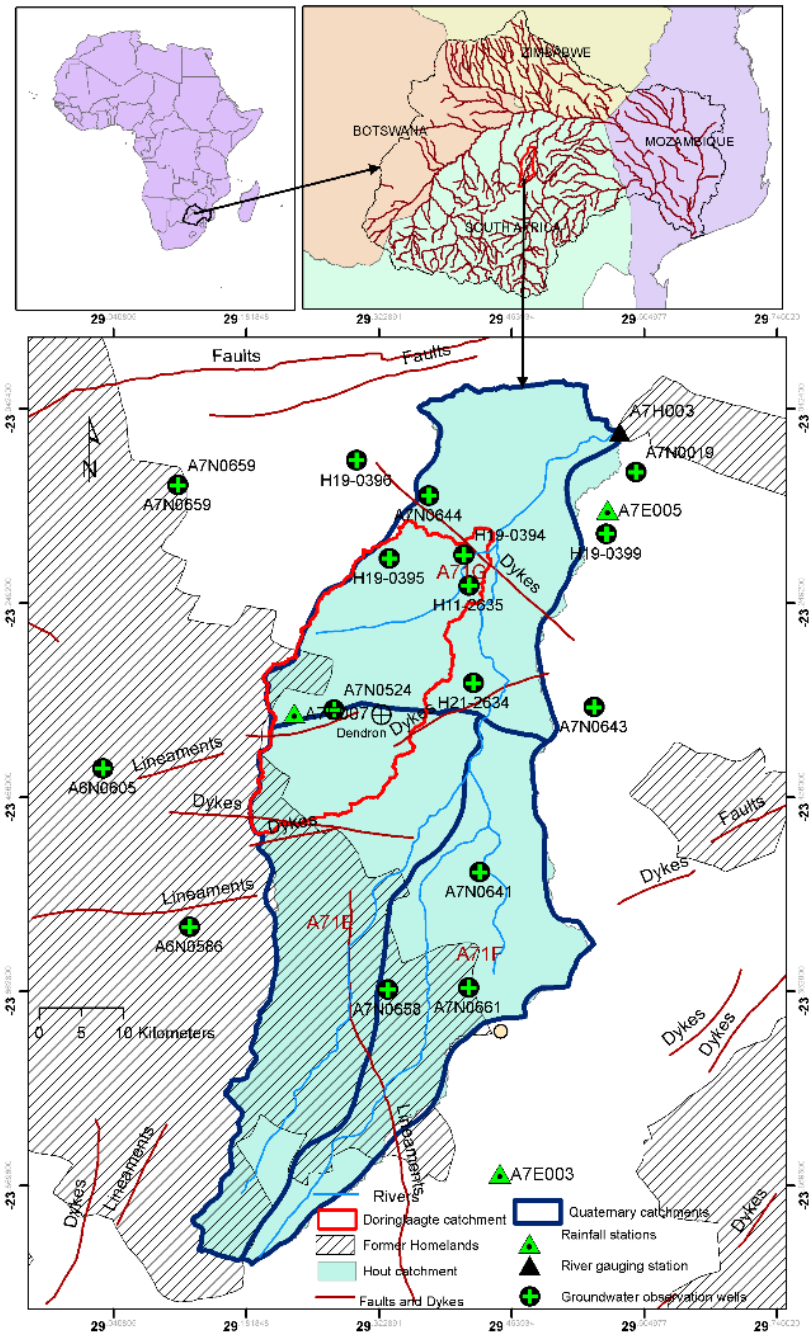


Figure 1: Map One Hout Catchment, Limpopo

Besides the Hout dam and smaller farm ponds, groundwater is the dominant water supplier, typical for South Africa in general where 74% of the rural population are completely dependent on groundwater – local wells and pumps (UNESCO WWAP 2006).

74% of rural population in Limpopo depend on groundwater for crops and domestic water supply

The Hout catchment has, for the purpose of natural grouping of CS volunteers and implementation purposes, been divided into three sections or segments (see map below). Sections one and three are inhabited mainly by smaller communities and smallholder farmers, while most commercial farmers reside in section two.

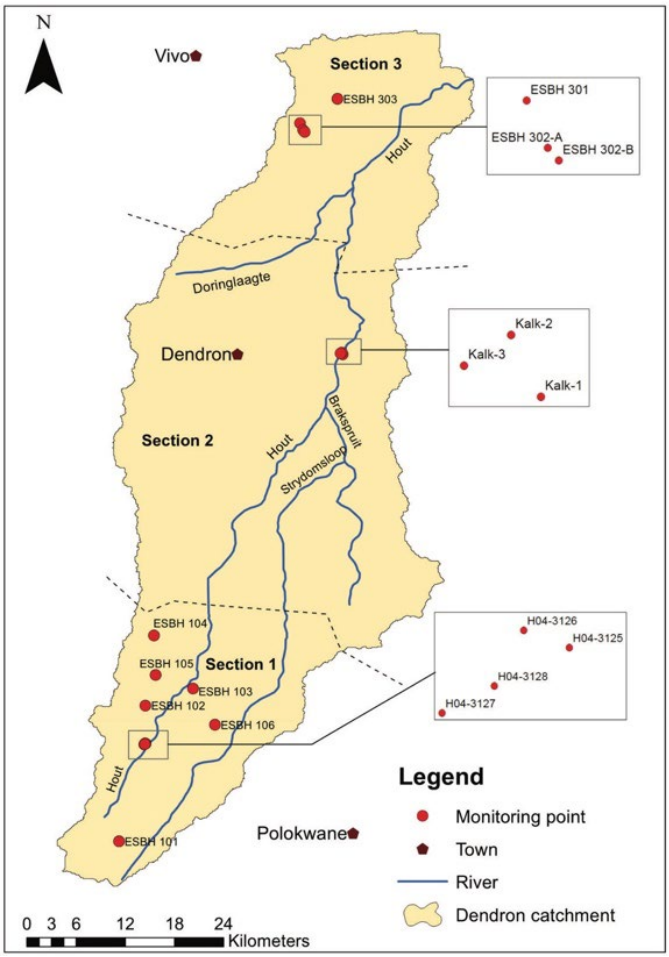


Figure 2: Map 2 Hout Catchment divisions into segments 1, 2 & 3

According to IGRAC (2013), the main aim of groundwater monitoring is to identify spatial and temporal trends, as well as comprehend how the groundwater changes are induced and their effect on the resource. Monitoring groundwater in the Hout becomes critical as it contributes to the body of knowledge on changes over time in groundwater levels and climate variabilities measured for instance by amount of rainfall or river flows (UPGRO, 2017). Groundwater resources are vulnerable to depletion and degradation if not protected and exploited in a sustainable manner. Mismanagement potentially leads to adverse impact effects on ecosystems,

water access, human health and agricultural production. As Mechlem (2016) reminds us, even where groundwater is formally a public good and users have only usufructuary rights, perceptions of it being "private" often linger on.

The proposed research has important strategic relevance for both the global north and global south. The research community and government concerned with water administration in the RSA benefit from the WRC capacity as well as the capacity of high-level Danish researchers who initiated the first phase of monitoring groundwater in the Hout through the ESGUSA project presented above. In terms of developing capacity for integrated groundwater management in RSA, the project supports the South African Groundwater Strategy (DWS, 2016). The project also strengthens capacity and application experience in citizen science and links to ongoing initiatives with DWS, DFFE[2], WRC[3], DSI[4] and others to establish a Citizen Science Society of Southern Africa.[5] The POPLUC model proposed in part five, will be relevant for projects that are not specifically to do with water but that are working across a humanities-natural science spectrum.

1.1.3 Groundwater resource management

Mechlem's paper on groundwater governance opens with the following extract from Frazier v Brown argued in 1861:

> The existence, origin, movement and course of (underground) waters, are so secret, occult and concealed, that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty and would be, therefore, practically impossible (argued by Frazier v Brown in 1861)

[2] Department of Forestry, Fisheries and the Environment

[3] Water Research Commission

[4] Department of Science and Innovation

[5] http://www.wrc.org.za/Lists/Events/DispForm.aspx?ID=399

Although groundwater has traditionally received less attention than surface water in policy and law, views as expressed in this quote above which were not uncommon in the 19th century, are by now fortunately obsolete. Nonetheless, a certain lack of attention to groundwater still manifests itself in piecemeal legislative approaches, inadequate institutional set-ups and insufficient implementation of groundwater law in many parts of the world. Increasingly, it is acknowledged that legal frameworks play a crucial role for effective groundwater governance, which need to flank and complement science and policy. Modern water laws take an integrative approach to surface water and groundwater resources, define clear rights and obligations, set up management tools, protect quantity and quality, involve stakeholders and are matched with robust institutions in charge of their implementation (Mechlem, 2016). A better understanding of the characteristics and nature of groundwater and increasing pressure on the resource have instilled a predominant trend to vest ownership and control over all water resources in the state or to recognize the state's superior right to the management of water resources. As such the state becomes the guardian or trustee of groundwater resources.

Groundwater resource management focuses on developing these resources sustainably without compromising their quantity and quality (Riemann et al., 2011). In some areas, aquifers have already been contaminated and overexploited due to the lack of management or/and inappropriate management and could further cause additional water supply problems and deterioration of ecosystems that are dependent on groundwater (DWAF, 2000; Kelbe and Rawlins, 2004). Therefore, strategies for groundwater management have been implemented and various guidelines driving groundwater management have been developed internationally, for the continent, SADC region and for the South African context. Groundwater management guidelines provide valuable information related to requirements and delineate steps that are vital for the protection and management of the aquifers.

However, groundwater cannot be managed in isolation; there has to be an integrated management of all water resources; surface and groundwater resources. According to DWAF (2000), monitoring, research, water quality guidelines, catchment management and auditing are integral parts of the integrated management strategies. Riemann et al. (2011) state quality and quantity monitoring over a long-term period, as well as using this information to assess whether compliance against rules and goals set by the Department of Water and Sanitation (DWS) are being met. It is important for water management to take into account political, social and environmental problems (DWAF, 2000). The management plans must include agricultural, mining, manufacturing, rural and urban development and ecological needs.

Water management is a combination of managing water resources and providing water services to citizens and these two functions although different, go together. The main objective of water resources management is protection, use, developing, conserving, managing and controlling water resources for environmentally sustainable social and economic benefits. Water-related laws have been useful in addressing this objective by protecting and managing the country's groundwater resources through appropriate strategic measures.

According to Ravenscroft and Murray (2004), groundwater management can be grouped into five main areas:

- Fulfilling legal obligations – ensuring use and protection of groundwater according to national and international laws
- Monitoring and analysing data – groundwater levels and abstraction
- Optimising groundwater usage
- Protecting groundwater from contamination
- Creating awareness and educating people about sustainable groundwater use

In the next section we move to the actors, the 'big' players – and as our discussion below in section two will show, actors are also 'things' such as laws and regulations. We consider thus the institutions and acts that deal with groundwater monitoring, the roles of many different stakeholders in groundwater monitoring such as the role of national government, district and local municipalities, unions, tribal authorities, etc.

Part Two: Big players

2.1 Meshing in with big players

As is clear from the section above, the need to protect, manage and develop groundwater resources has become increasingly important due to the increase in demand for usage of these resources and surface water resources in semi-arid regions being exploited to their capacity. It is helpful to consider groundwater management in South Africa within the broader international context as well as to identify protocols stipulated by 'big players.' As we turn to the 'big players' who are involved in groundwater management we remind the reader that our list is not exhaustive. We will look briefly at the Southern African Development Community (SADC), the African Development Bank Group (ADBG), New Partnerships for African Development (NEPAD) and the Global Water Partnership Southern Africa (GWP-SA). We also look at Catchment Management Agencies (CMA) where we will provide some examples before turning to Water User Associations (WUAs) where again, we look at specific examples of transformation from Irrigation Boards to WUAs. We then turn briefly to the role of the Department of Water and Sanitation (DWS), Department of Forestry, Fisheries and the Environment (DFFE), Department of Agriculture, Land Reform and Rural Development (DALRRD), and the Department of Mineral Resources and Energy (DMRE). We will then go on to look briefly at water related laws.

2.1.1 Southern African Development Community (SADC) on Groundwater Management

The Southern African Development Community is an inter-governmental organization and consists of sixteen member states, countries located towards the south of the African continent. Approximately 70% of the population in the SADC region are dependent on groundwater as a primary source of water (SADC, 2014). Groundwater is an essential buffer between dry and rainy seasons, although the SADC Member states have varying dependency on this water resource. This dependency has resulted in some SADC member states integrating groundwater in their water resources management policies and laws (SADC, 2014).

The SADC member states signed the "Protocol on Shared Watercourse Systems in the SADC Region" in 1995. The "Revised Protocol on Shared Watercourses" which is legally binding, later replaced this Protocol in 2000. The objective of the revised protocol is to nurture closer cooperation amongst member states in support of judicious, sustainable and co-ordinated management, protection and utilisation of shared watercourses and advance the SADC agenda

of regional integration and poverty alleviation (SADC, 2000). The watercourses include shared river basins, and transboundary aquifers. According to the International Groundwater Resources Assessment Centre (IGRAC), the SADC now considers groundwater management essential; this has led to the development of regional management programmes to improve groundwater management practices in Southern Africa, such as the Groundwater Management Programme (IGRAC, 2013). Of relevance too is the SADC Regional Water Policy, the Regional Water Strategy and Regional Strategic Plans that guide water management at the scale of the Region. Of significance too are River Basin Organisations, in particular ORASECOM and LIMCOM which are major actors in the Region. The Southern African Development Community Groundwater Management Institute (SADC-GMI) was founded to be the regional centre for groundwater. The roles of the SADC-GMI as presented by Pietersen and Beekman (2016) include:

- Promoting sustainable groundwater management and solutions to groundwater challenges in the SADC region through building capacity, providing training, advancing research, supporting infrastructure development, and enabling dialogue and exchange of groundwater information
- Conducting and supporting SADC member states in groundwater research, and serve as a focal interlocutor with national, regional and international groundwater initiatives

There have been numerous efforts to understand and manage groundwater in the SADC. These include:

- Transboundary Water Management in SADC Programme, which ran from 2005 to 2015
- Groundwater and Drought Management Project (GDMP) in 2009
- SADC Hydrogeology map which provides information on the extent and geometry of regional aquifer systems
- SADC Groundwater Grey Literature Archive which made useful information on African groundwater more accessible
- SADC-GIP which is a groundwater map based information system providing access to the harmonised SADC hydrological map and atlas

The SADC-GMI, International Groundwater Resources Assessment Centre and Institute for Groundwater Studies (IGS) have developed a framework for groundwater data collection and data management for the SADC. This framework is instrumental in driving implementation of

policies and strategies using the existing technical guidelines (SADC-GMI, 2019). Furthermore, various aspects of groundwater data collection and data management are addressed by the framework. These include borehole siting and drilling, groundwater monitoring, field data collection, databases, and data sharing and reporting; which are essential for effective groundwater management. If groundwater in southern Africa is well managed, it could ensure long-term water supply to meet the increasing demands brought by the anticipated climate variability (SADC-GMI, 2019) But as the table below shows national monitoring networks are inconsistent within the SADC region and data management is often absent. There are challenges such as establishment of a network, financial resources and so forth.

Table 1: National groundwater monitoring networks in 9 SADC countries[IGRAC, 2013]

	National Monitoring Network	Data management	Challenges
Angola	*DNA, Poorly developed*	*None*	*Establishment of network*
Botswana	*Yes, DGS, DWA since 1971*	*National Borehole Archive (NBA)*	*Spatial density of wells, coordination of the work*
Lesotho	*Yes, DWA, since 1990 >150 springs and > 60 wells*	*Database linked to GIS*	*Financial resources, public awareness*
Mozambique	*Pilot Project, Ara-Sul >25 gw monitoring wells >45 gw quality mon. points*	*Poorly developed*	*Establishment of network, professional capacity building*
Namibia	*Yes, DWA, since 1960 > 650 gw monitoring wells*	*GROWAS, database linked to GIS*	*Human capacity, evaluation of data*
South Africa	*Yes, DWA >2500 gw monitoring points >350 gw quality mon. points*	*National Groundwater Archive (NGA) Web-enabled database linked to GIS.*	
Tanzania	*Yes, Ministry of Water, since 1955 >75 gw monitoring wells*	*Database*	*Institutional capacity, Coordination of the work*
Zambia	*Yes, DWA*	*Database linked to GIS*	*Financial resources, coordination of the work*
Zimbabwe	*Yes, ZINWA 3 aquifers are monitored*	*Hydro GeoAnalyst, database linked to GIS*	*Financial resources, human capacity*

2.1.2 African Development Bank Group (ADBG)

The ADBG has policies on water; the 2000 Integrated Water Resources Management Policy and the new 2020 Water Policy, which seeks to support the development and improved management of water resources and water security at household, national, and regional levels in Africa (ADBG, 2020). The Bank Group aims at improving water security and transforming water assets to nurture sustainable, green and inclusive socio-economic growth and development in Africa through the implementation of its new policy on water. Furthermore, the Bank Group

advocates for an integrated approach to develop and manage water resources by maintaining balance in the social, economic and environmental sectors.

The Bank Group is committed to promote water security in Africa and aims at advancing the Sustainable Development Goal (SDG) agenda. According to the new water policy, the Bank advocates for proper management of transboundary water resources to enhance regional integration and resolve arising conflict among countries sharing transboundary watercourses. However, the Bank Group policies on water consider water resources as a single entity and do not necessarily focus on groundwater resources in particular. The Bank has developed monitoring systems that focus on security dimensions, such as availability and quality, demand, economic, social and environmental benefits, as well as pressure from climatic variability and human activities. These monitoring systems are important in ensuring that water resources are used in a sustainable manner. The monitoring systems enable implementation of measures to mitigate groundwater table lowering, surface water resources pollution and the decline in flow of major river systems to make sure that integrated management of these water resources takes place (ADBG, 2020). To ensure that the mandate to protect, use, develop, conserve, manage and control South Africa's groundwater resources is followed, the monitoring of these resources has to take place.

2.1.3 New Partnerships for Africa's Development (NEPAD)

NEPAD was designed to address the development challenges that the African continent faces (NEPAD, 2003). NEPAD launched the Environment Initiative, for which the action plan took the following sectors and cross-cutting issues as priority areas: combating land degradation; drought and desertification; wetlands; invasive species; marine and coastal resources; cross-border conservation of natural resources; climate change and cross-cutting issues. According to NEPAD (2003), the action plan builds up on issues of pollution, forests and plant genetic resources, fresh water, capacity-building and technology transfer. Depletion and deteriorating quality of freshwater resources were identified as one of the key areas of focus. Freshwater resources include rivers, lakes, groundwater and wetlands. NEPAD (2003) states that wetlands are crucial for maintenance of the water table as they facilitate the movement of large volumes of water into groundwater resources, thereby recharging the aquifers. The NEPAD programme for conservation of Africa's wetlands focuses on ensuring that African citizens have healthy and productive wetlands to support human needs, clean water, sanitation, food security and economic development. Development of surface and underground water resources was identified as one of the key issues that have to be dealt with during a NEPAD thematic workshop

on coastal and marine resources. NEPAD commissioned a project focused on reducing environmental impacts from coastal tourism by introducing policies and strengthening public-private partnerships to deal with issues that include but are not limited to surface and groundwater resources, groundwater vulnerability as well as transboundary aquifer management. According to NEPAD (2003), the transboundary approach within the Environment Initiative for sustainable use and conservation of natural resources, is aimed at protecting groundwater resources as these are important to many Africa countries. The African Development Bank established a trust fund to support NEPAD in financing water and sanitation infrastructures across the African continent. NEPAD has commissioned projects for capacity-building, strengthening of institutions, technical and scientific cooperation; as well as support to legislative, regulatory and economic reforms. In 2007, the SADC Groundwater and Drought Management Programme was established by NEPAD. This programme had six sub-projects that focused on capacity building for groundwater management; establishing a regional groundwater information system and groundwater monitoring network; compiling a regional-geological map and atlas for the SADC region; establishing a regional groundwater research institute as well as groundwater assessment of the Limpopo river basin (NEPAD, 2012).

2.1.4 Global Water Partnership-Southern Africa (GWP-SA)

In 1996 GWP was established with the aim to support countries with managing their water resources sustainably. GWP is mainly focused on Integrated Water Resource Management (IWRM). GWP works through regions to perform its tasks and missions effectively, one of which is Southern Africa. The mission of GWP-SA is to promote collaboration, as well as sustainable use and management of water resources in Southern Africa. Lack of awareness around IWRM contributes to uncoordinated management of water resources in Southern Africa. Therefore, the Southern African Water Information Network (SAWINET) was established by GWP-SA to address the problem of lack of awareness and information. SAWINET is a framework that facilitates the dissemination of IWRM information; this network contains among other things water policy and legislation, catchment and groundwater data. The network contains information on transboundary catchments and groundwater data that includes water levels, geographic area and quality as obtained from groundwater monitoring in different regions, The network also provides information on how to organise water management at the catchment level and how to deal with groundwater issues using technical information and approaches. SAWINET publishes reliable information from verifiable and contactable sources.

2.1.5 Catchment Management Agencies (CMA)

The responsibility of CMAs is water resource planning at the very local level. DWS delegates water resources management activities to CMAs, such as water use licencing and discharges; monitoring abstractions and discharges; collecting abstraction and discharge fees; monitoring water quality and quantity; overseeing land-use activities that affect water management; developing catchment management strategies; supporting other institutions; implementing water resources infrastructure; managing information and auditing water resources management. In addition, the role of CMAs initially was to investigate and advise interested parties on water resources management; coordinate functions of other institutions involved in water related matters as well as involve local communities in water resources management. The Minister delegates duties and other powers to a CMA depending on its size and capacity. It is important to note that CMAs are focused on integrated water resources management, as both the surface and groundwater resources are present within their areas of jurisdiction.

This section discusses the Breede-Gouritz and Inkomati-Usuthu CMAs, because they are the only two that have been established. The others are battling to get off the ground. There were originally going to be 19 covering all 19 Water Management Areas in South Africa and this was reduced to 9 in 2012 (Water Wheel, 2007, Meissner et al., 2016). During the 2019/2020 review period, the DWS developed and submitted the proposal and roadmap for the establishment of six CMAs in the Limpopo-Olifants, Mhlatuze-Mzimkhulu, Vaal-Orange, Mzimvubu-Tsitsikamma and Breede-Olifants. and Phongola/Umzimkulu water management areas (DWS National State of Water Report, 2021).

2.1.5.1 Breede-Gouritz CMA (BGCMA)

The BGCMA operates in the south-eastern part of the Western Cape Province. This CMA specifically deals with water licencing with the aim of speeding up the licencing process and enabling local people to take part in the management of water resources (Sadiki and Ncube, 2020). Programmes that promote water allocation to smallholder farmers through the DWS subsidies and grant licences for agricultural water use are of priority to the BGCMA. The BGCMA strategy guides the management of water resources such as to address social inequality while prioritising water reallocation. However, lack of funds makes the implementation of Water Allocation Reform complicated (*ibid.*). Sadiki and Ncube (2020), note that the BGCMA has encountered challenges relating to socio-political and financial factors, water quality and quantity, technical capacity and capabilities. According to the Parliamentary Monitoring Group (PMG), the BGCMA has managed to raise awareness of management of water resources

through institution and stakeholder relations initiatives that have been implemented involving 25 000 learners and stakeholders. The BGCMA members generally appreciated the awareness presentations and emphasised the importance of having strict consequences for polluters, as pollution has severe impact on water resources and those living downstream (PMG, 2021) The BGCMA has a policy to support projects related to water resource management, such as food gardening and rain harvesting tanks (*ibid.*).

2.1.5.2 Inkomati-Usuthu CMA

The Inkomati-Usuthu CMA plays a vital role in promoting a culture dialogue among water users to ensure that water resources are shared equitably and sustainably (Water Wheel, 2007). This CMA initiated outreach programmes targeting the rural people, emerging farmers, women and youth; with the aim of raising awareness around water resources management (*ibid.*). The CMA considers the verification and validation of water use and expansion of water monitoring networks important aspects of water resources management (PMG, 2021). According to the PMG (2021), the CMA is in the process of implementing disaster management protocols and is embarking on river cleaning, removal of alien vegetation, as well as water conservation and management.

2.1.6 Water User Associations (WUA)

Karar et al. (2011) and Pegram and Mazibuko (2003) state that WUAs are "cooperative associations of water users established under the NWA to undertake water-related activities for the mutual benefit of their members within a designated area." One of the responsibilities of WUAs is to manage local water infrastructure and implement management decisions (Karar et al., 2011). WUAs are also responsible for collection of water-use charge fees. Irrigation Boards are currently being transformed into WUAs; as the latter provides a statutory body that can perform functions at a local level, delegated by a CMA (Pegram and Mazibuko, 2003). Pegram and Mazibuko (2003) state that WUAs may be established solely for controlling recreational use of water or irrigation. Therefore, depending on the area covered by the WUA, surface and groundwater uses; waste discharges and domestic-industrial abstractors may require management to ensure protection and conservation of the water resources. WUAs use the legal framework specified within the NWA and sometimes the WSA to perform their

functions (Pegram and Mazibuko, 2003). This legal framework is also important for the establishment of WUAs and transforming of IBs into WUAs.[6]

2.1.7 Transformation of Irrigation Boards (IBs)

Irrigation Boards are required to transform into WUAs as specified in Section 98 of the NWA. IBs have mainly been composed of commercial farmers and excluded all other water users and historically only focused on irrigation. Their transformation has been to include all other water users in their area of jurisdiction and expand their membership to new members from other sectors as well as to broaden their functions and activities (Pegram and Mazibuko, 2003; Faysee and Gumbo, 2004). New sectors to be included in the WUAs are local government institutions, ordinary water users (household), industries, emerging farmers, small scale farmers, municipalities, recreational bodies and forestry representatives (Pegram and Mazibuko, 2003; Orne-Gliemann, 2008). According to Faysee and Gumbo (2004), transformation of IBs is believed to enable historically disadvantaged individuals (HDIs) to participate in water resource management. HDIs include people who were previously discriminated, such as Blacks, Coloureds, Indians, women and people living with disabilities (Faysee and Gumbo, 2004). Transforming IBs are required to have a constitution based on Schedule 5 of the NWA that specifies the principal and ancillary functions of the WUAs; voting powers of members; procedures for terminating membership; procedures for appointment of employees of the association; procedural requirements for obtaining loans; and the financial obligations of members towards the association (Pegram and Mazibuko, 2003). All water users from the different sectors have to be represented in the management committee of the association. Although there are 90 WUAs (new WUAs and transformed IBs), there are currently still 220 Irrigation Boards in existence that have not yet transformed into WUAs (Dini et al., 2021). Meissner et al. (2013) state that the transformation of IBs into WUAs in conjunction with decentralisation of the management of water resources are continuous processes. Most IBs have not yet transformed into WUAs.

2.1.7.1 The Great Letaba WUA

As this is relevant to the Limpopo, we present below a case study example of the Great Letaba WUA which was transformed from the Letaba IB which was founded in 1960 under the previous Water Act (Act 54 of 1956) in November 2001 (Seshoka et al., 2004; Pollard and Du Toit, 2011; Meissner et al., 2016). This WUA is in the Mopani District Municipality in the Limpopo

[6] Of relevance is the establishment of the Mokolo Water User Association whose area of operation is the total Mokolo River Catchment Area (quaternaries A42A and A42J in the Limpopo Water Management Area

Province; covering the area within the former Lebowa and Gazankulu homelands (Pegram and Mazibuko, 2003; Seshoka et al., 2004). The main function of the Letaba Irrigation Board was for irrigation development and water supply and commercial farmers were the only members (*ibid.*). The WUA is currently comprised of commercial farmers from the previous Irrigation Board; new members from the former homeland areas, which includes small-scale farmers and individual water users; industry; local municipality (Pegram and Mazibuko, 2003). Furthermore, the Great Letaba WUA has built meaningful relationships with other institutions in the area, such as traditional authorities, private game reserves, recreational institutions and other community areas that formerly were part of Gazankulu (*ibid.*). The management committee of the Great Letaba WUA is made up of the following representatives:

- Members of commercial farmers
- Members of individual water users that does not receive water from any local municipality
- Member from local authority (municipality)
- Tribal authority member

It is crucial for tribal authorities to be included in WUAs, especially in the rural areas because they are part of the governance. According to Peters and Woodhouse (2019), after the end of apartheid former homeland areas were merged with neighbouring 'white' magisterial districts. Tribal (traditional) authorities have the authority to govern land allocation and perform local administrative tasks, since the apartheid era (Peters and Woodhouse, 2019). Furthermore, chiefs allocate and issue communal lands while the municipal delivers public services; therefore, representatives from these levels of government are vital for the transformation of IBs to be approved by the Minister (Peters and Woodhouse, 2019). According to Peters and Woodhouse (2019), private properties, such as homes, businesses and irrigated farms exist in the land allocated by tribal authorities. Therefore, the involvement of tribal authorities in the management of WUAs is to represent the interests of rural communities to ensure that they are also included and considered in the management of their water resources (Seshoka et al., 2004).

2.1.8 Department of Water and Sanitation (DWS)

The National DWS office delegates the responsibilities of water resource management to regional offices. According to Pietersen et al. (2012), the DWS is also responsible for implementing agents that develop water resources policies and strategies, as well as audit CMAs. In 2010, the DWS formulated a National Groundwater Strategy (NGS) with the aim of

addressing the shortcomings of the National Water Resource Strategy. The Groundwater Resource Protection theme (theme four) of the NGS states that approaches for pro-active groundwater protection and aquifer-dependent ecosystems should be developed and maintained to ensure sustainable water supply without impacting on groundwater resources (DWS, 2016). According to DAFF (2015), the NGS is instrumental in paving the way to the development and implementation of groundwater management programmes made to meet the quality and quantity requirements. The DWS has a comprehensive groundwater quality protection strategy that states that "as the country's people start to depend more and more on groundwater, so the need grows to provide for the security of its supply. Protection of groundwater has, therefore, now become a national priority" (DWS, 2016). According to DWS (2016), the protection of community water supplies by preventative measures means there is the highest requirement for groundwater protection. Therefore, the preventative means include minimum requirements for borehole construction, control of land-use around abstraction points and site-specific protection of the aquifer. The DWS embarked on a project focused on investigating the successful registration of drilling contractors, as well as the mechanism for training and control. In 2007 the DWS initiated a project with the University of the Western Cape named "Feasibility study towards the policy development on aquifer protection zoning" aimed at zoning of land for different purposes to ensure protection of groundwater resources (DWS, 2016). However, this project was not followed through.

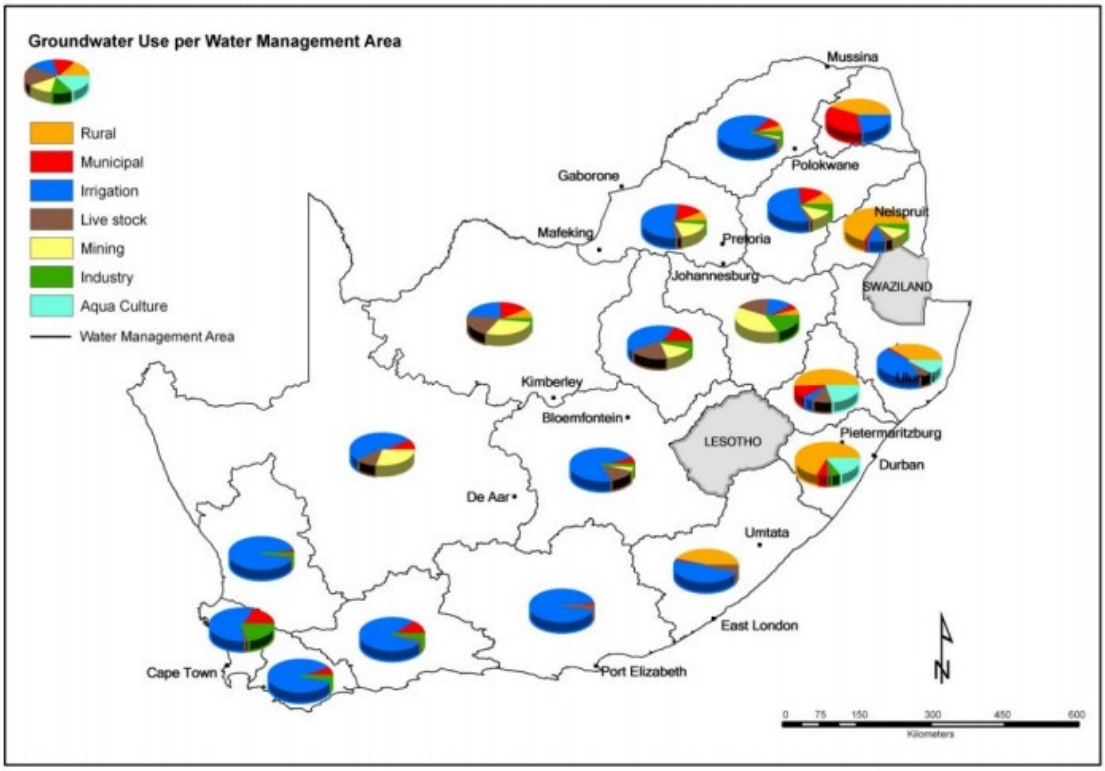
According to DAFF (2015), to deal with unlawful water users, legal actions, water pricing, water tariffs, authorisation and licensing of water use, construction and maintenance of bulk infrastructure, as well as policy developments, the DWS consults with other departments to ensure proper departmental alignment (e.g. Department of Forestry, Fisheries and the Environment; Department of Agriculture, Land Reform and Rural Development, Department of Mineral Resources and Energy, Department of Health, Department of Tourism, Department of Human Settlements). The National Water Act and Water Services Act enable the Minister through the DWS to establish CMAs, WUAs, Water Boards and WMAs to ensure water resource management at all government levels. The DWS is also responsible for installation and maintenance of groundwater infrastructure such as boreholes, pumps, piezometers, data loggers, etc. The DWS is focused on national policy and legislation, water resource management regulatory framework and making sure that other departments and institutions fulfil their roles and responsibilities effectively (Stephan et al., 2019).

2.1.9 Department of Forestry and Fisheries and the Environment (DFFE)

The DFFE has the responsibility to protect, conserve and maintain environmental quality in support of the right of all South African citizens to an environment that is not harmful to their health (DEAT, 2014; Pietersen et al., 2012). Potential groundwater users are required by the DFFE and DWS to obtain a licence or authorisation when conditions and levels of use are exceeded (Pietersen et al., 2012). These levels and conditions differ according to provinces and catchments. However, no water use licence is required for schedule one which is water used for domestic purposes in households (DWAF, 2007). The DFFE has policies and legislation that support groundwater management. For instance, the National Environmental Management: Air Quality Act of 2004, which regulates greenhouse gases and their potential impacts on the water environment. Greenhouse gases in the atmosphere, such as carbon dioxide, nitrous oxide, etc. absorb heat, resulting in global warming which causes climate change. Climate change may result in increases of water temperature, changes in precipitation amounts which eventually affects the amount of water available in the water resource components (surface and underground water). Greenhouse gases can be linked to increases in pathogens, nutrients, pollutants, such as ammonia, methane; changes in the concentration of dissolved oxygen in the water, thereby changing the quality of the water (Nikolenko et al., 2019). The National Environmental Management: Waste Act of 2008 requires reasonable measures to be taken to prevent pollution and remediate the land that may negatively affect water resources (Pietersen et al., 2012). According to Pietersen et al. (2012), in South Africa groundwater is often neglected. This is evident in the numerous pollution incidences throughout the country and the incapability to deal with the serious mine water problem (Pietersen et al., 2012). The DFFE is committed to raising awareness about the impact of pollutants on groundwater resources especially due to the importance of the resources in the environment and ecosystems. Furthermore, the DFFE is committed to ensuring that the environmental legislation considers groundwater in land use planning such as solid waste sites. Through the related legislation, the DFFE requires Environmental Impact Assessments (EIAs) for every project that could potentially harm the environment (DEAT, 2004). According to DEAT (2004), the EIAs provide the government with the necessary information needed to make informed decisions about developments and how to control or mitigate their impacts. The DFFE has an approach that reduces the release of waste streams (sewer or liquid waste) into the environment or landfills, as this waste might eventually find way into the surface water bodies and underlying aquifers (DEAT, 2004). DAFF (2015) states that the main responsibility of the DFFE is the implementation of environmental laws and adherence of relevant stakeholders to these laws including submission of EIAs.

2.1.10 Department of Agriculture, Land Reform and Rural Development (DALRRD)

The agriculture sector uses more water compared to other sectors, for irrigation and afforestation. For this reason the DALRRD has divided water management into water supply management and water application (irrigation) management (DAFF, 2015). The responsibility of the DALRRD in relation to water management is to develop basic implementation of guidelines for renewal of irrigation schemes, as well as efficient water use and management (DAFF, 2015). The DALRRD also has the responsibility to fund, support and monitor the implementation of irrigation projects within the country to ensure sustainable use of water resources. According to DAFF (2015), the National Groundwater Strategy formulated by the DWS in 2010 represents authoritative figures for groundwater volumes that can be extracted sustainably for use for the whole country and each of the (then) 19 WMAs. South Africa has limited water resources, therefore, the majority of irrigation schemes extract water from groundwater sources making agricultural irrigation the largest user of groundwater in comparison to other sectors as seen in map four below.



Source: DWS (2016)

Figure 3: Groundwater usage per water management area

Water supply management ensures the availability of adequate supplies of irrigation water to lawful irrigation farmers (DAFF, 2015). The DALRRD has guidelines for irrigation system selection, design and maintenance to ensure proper water use during irrigation. The DALRRD, DWS, DFFE and other relevant stakeholders are responsible for the development of guidelines

on all aspects of irrigation planning, development and management to ensure sustainable use of water resources. Stevens and Van Koppen (2015) state that the responsibilities of the DALRRD and DWS include investing in agricultural water development and infrastructure necessary for bulk water distribution within the country without greatly impacting on the quality and quantity of the resources.

2.1.11 Department of Mineral Resources and Energy (DMRE)

As Prasad et al. (2012) state, energy and water are closely linked at different levels and scales. According to this statement, water is vital in energy related matters and vice versa; the two are inseparable. Water is crucial for driving the turbines of hydroelectric power plants and cooling stream electric power plants fuelled by coal, oil, natural gas and nuclear power. Energy is crucial in the purification and distribution of water to consumers (Prasad et al., 2012; Etzinger, 2012). According to Prasad et al. (2012), climate variability that leads to floods and droughts is due to greenhouse gases released into the atmosphere by coal-based power plants. The droughts and floods caused by climate change lead to crop failure (food insecurity) and interfere with water supply technologies (Prasad et al., 2012). Therefore, it is important to understand the water-energy nexus in order to increase resource use efficiency and ensure sustainable access and use of water and energy while adhering to related policies and legislation (Prasad et al., 2012). The DMRE formulated an Integrated Resource Plan (IRP) in 2010 to serve as input to other planning functions, economic development, funding, environmental and social policy formulation (DoE, 2010). The IRP requires water to be quantified for each technology (DoE, 2010). Prasad et al. (2012) state that integrated water and energy plans have been prepared and updated regularly by the DMRE in support of the country's long tradition of integrated water resource management which is inclusive of the impact of climate change on water resources. According to DWS (2015), the DMRE, DWS and the National Treasury commissioned an investigation into the prospects of adding equipment for hydroelectric generation at existing DWS dams that have the potential to be used for hydroelectricity generation. Furthermore, WRC and Eskom collaborated to fund and research energy and water use related issues (Etzinger, 2012). The DMRE is committed to supporting development of renewable energy technologies. In December 2011, the DMRE announced 28 successful bidders for renewable energy projects that include solar photovoltaic, onshore wind projects and concentrated solar power projects (Etzinger, 2012). This was aligned with the need for water resource management as renewable energy technologies hardly use any water.

2.1.12 Tribal Chiefs

Post-apartheid South Africa has a dual governance system comprised of national, provincial and municipal governance institutions led by elected officials and of "traditional" institutions led by unelected traditional leaders. Government requires a combination of options and use of a multi-sectoral approach to ensure efficient delivery of services. This can help reduce the burden on the three known spheres of government in a mutually re-enforcing way. The Constitution also indicates that national legislation may provide a role for traditional leadership as an institution at local level on matters affecting local communities (Zingisa, 2013).

Despite the fact that traditional leaders are recognised by the South African Constitution (Sections 211-212), their authority and powers in terms of water management are not augmented by legislation. The NWA does not explicitly recognise customary water management structures, practices and laws (Malzbender et al., 2005).

Prior to the introduction of colonialism, social organisation in South Africa was characterised by a number of tribal regimes based on patriarchy and inscriptive norms. Each tribe, as is still the case, has a traditional leader as the central figure. The traditional leader was the highest authority in the territory and had various functions which were not exercised autonomously by an individual, but in collaboration with a tribal council that represented the people. Nearly two decades after South Africa's democratization, questions of tradition and accountability continue to trouble the polity (Turner, 2014). Contemporary traditional leaders exert substantial – albeit ill-defined and contested – authority within the boundaries of their so-called traditional communities, presiding over meetings, resolving disputes, interpreting customary law, allocating communal land, mediating between external actors and their subjects and granting or withholding support for development initiatives (Turner, 2014).

Figure 4: Tribal Authorities caucus

Fourteen and a half million black South Africans remain subject to state-recognized so-called "traditional leaders" such as kings, queens, chiefs, regents, headmen and headwomen (Turner, 2014). The Traditional Leadership Governance and Framework Act of 2003 retained the traditional leaders, tribes (now called "traditional communities"), tribal authorities ("traditional councils") and boundaries in place at that time (ibid).

Fourteen and a half million black South Africans remain subject to state-recognized so-called "traditional leaders" such as kings, queens, chiefs, regents, headmen and headwomen

In a new democratic South Africa, the government immediately recognised the role of the traditional leadership and included the institution of traditional leadership in the 1996 Constitution. The Constitution states that "the institution, status and role of traditional leadership, according to customary law, are recognized, subject to the Constitution." The White paper on Traditional Leadership and Governance that was adopted and approved in 2003 proposes

and tabulates a variety of duties and functions which can be discharged by traditional leadership institution, namely:

- Promote socio-economic development, good governance and services delivery, especially in rural areas
- Ceremonial role – serve as custodians of culture, tradition and custom

Because a large number of people reside in rural areas, it is necessary that government should not only rely on the national, provincial and local spheres of government with regard to the delivery of services, but should utilize, for example, the institution of traditional leadership. Government requires a combination of options and use of a multi-sectorial approach to ensure efficient delivery of services; this can help reduce the burden on the three known spheres of government in a mutually re-enforcing way.

The Constitution also indicates that national legislation may provide a role for traditional leadership as an institution at local level, on matters affecting local communities (Zingisa, 2013). In South Africa, early systems of governance were characterized by traditional leadership rule. Traditional leaders and institutions dealt with a wide range of issues relating to their communities. A king or chief was regarded as the father figure or head of the community or tribe. The chief was responsible for the welfare of his / her people including peace and harmonious co-existence, dispute resolution, promotion of agriculture and indigenous knowledge system (Mahlangeni, 2005).

South Africa has approximately 800 traditional leaders, who may be assisted by 10 or more subordinate leaders resulting in a total of some 10 000 traditional leaders. Any decision on traditional leaders and institutions could therefore affect nearly 40% of the South African population (Selepe, 2009). Furthermore, over 18 million rural people (about 40% of the national population) live under the jurisdiction of traditional leaders (Tapela, 2015) and are distributed in seven of the nine provinces. Traditional leadership is an institution that has developed over many hundreds of years in Africa. It has served the people of Africa through wars, periods of slavery, famine, freedom struggles, economic and political restructuring and during colonial and apartheid periods. The institution of traditional leadership is rooted in Africa and in the hearts and minds of all ordinary Africans taking pride in its history, culture, origin and identity. Central to the institution of traditional leadership, customs, traditions and cultural practices form the basis of the legal system which regulates the lives of the people (Selepe, 2009).

Prior to the introduction of colonialism, social organisation in South Africa was characterised by a number of tribal regimes based on patriarchy and inscriptive norms. As is clear from our discussion above, this is still the case as each tribe has a traditional leader as the central figure. The traditional leader was the highest authority in the territory and had various functions which were not exercised autonomously by an individual, but in collaboration with a tribal council that represented the people.

The people saw the traditional leader not only as a link between people and the ancestors but also as a spiritual, cultural and judicial leader and the custodian of the values of the community. The traditional leader was the co-ordinator of the various aspects of everyday life, the realisation of community dreams and aspirations and the creator of harmony between people and the natural, spiritual, social and economic environment. Presenting themselves as authentic custodians of African culture, custom and identity, traditional leaders won the "struggle over the soul of custom" despite sustained opposition from activists in the fields of gender equality, land rights and democracy, as well as from citizen-subjects (Oomen, 2007).

Dick Sklar (1986) writing many decades ago, has argued for the recognition of "mixed government" as providing an increasingly widespread and important foundation for political rule in Africa today. From this perspective, "architects of government" on the continent are increasingly turning to a new form of rule that "conserves traditional authority as a political resource without diminishing the authority of the sovereign state." We, like Bank and Southall (2013) choose to look positively rather than negatively at Africa, where most countries are widely dismissed as groaning under the 'dictatorship of poverty' and the 'poverty of dictatorship' – and we will find that the continent actually constitutes a 'veritable workshop of democracy.' Sklar's concept of mixed government, and his conception of Africa as a laboratory of democratic forms, can serve as a useful starting point for the examination of the role and prospects of traditional authorities under the new Constitution in South Africa.

Bank and Southall (2013) present the following insights beyond the local level, although it allows them no direct representation in the new legislatures, it does provide for traditional leaders to play an advisory role at both regional and national levels of government. Legislatures of each province in which there are recognised traditional authorities will establish Houses of Traditional Leaders, composed of representatives elected or nominated by such authorities in the province concerned. These Houses will have the right to be consulted by and to advise and make proposals to, the provincial legislatures concerning traditional matters or indigenous law and

customs. Opposition by a provincial House to any Bill concerning such matters will restrain regional legislatures from passing that Bill for 30 days.

Similarly, the advisory Council of Traditional leaders, consisting of a chairperson and 19 representatives chosen by an electoral college constituted by members of the Houses of Traditional Leaders, will be established to make recommendations to the national parliament, and will likewise possess delaying powers of 30 days. The Council may also be requested by the President to advise him or her on any matter of national interest.

In search of a National role during the years 1987-1994, the Congress of Traditional Leaders of South Africa (CONTRALESA) was formed by KwaNdebele chiefs and headmen in September 1987 during the struggle against independence in that homeland. The broad aim of the organization was to oppose the homeland system. According to its constitution, CONTRALESA sought to unite all traditional leaders and to school them in the politics of liberation, to fight for the eradication of the Bantustan system, to win back the lands 'stolen' from their forefathers during colonialism, and to contribute to the struggle for a "unitary, non-racial and democratic South Africa" (Bank and Southall, 2013). At the official launch of CONTRALESA as a national body, Chief Holomisa emphasised that the primary objective of his organization was to restore 'dignity, reverence and respect' to the ancient institution of chieftaincy, which had been manipulated and abused by the apartheid regime. He stressed that chiefs must shed their image as collaborators and government 'sell-outs' and had to prove that they were 'worthy leaders' who could make a real contribution in the struggle for national liberation. Furthermore, he suggested that chiefs would have to become more receptive to processes of democratization at the village level and should make themselves 'accountable' for their actions at the local level. In particular, he pointed out that they would have to learn to co-exist with democratically elected residents' associations (Bank and Southall, 2013).

Bank and Southall (2013) ask crucial questions under their heading of ‘mixed government or mix up in the new South Africa?’ In particular, they pose the question whether traditional leadership sustains or subverts the making of South Africa's new democracy? Does the principally advisory role provided for chiefs under the new Constitution achieve an appropriate balance between democracy and tradition? Will the proposed arrangements harness the progressive, and discard the repressive, aspects of the traditional leaders' ambiguous tradition? Will the new Constitution, in the words of the ANC's guideline of 1988, ensure that the "institution of hereditary rulers and chiefs shall be transformed to serve the interests of the people as a whole in conformity with ... democratic principles?" Support for the institution of chieftaincy, and the

traditional values of consensus and discussion that it supposedly represents, remains widespread in the former Bantustan areas of South Africa, suggesting that it could indeed perform a complementary role to democratic structures of government.

The research of Kapfudzaruwa and Sowman (2009) suggests that there seems to be limited space in the new water management institutions at the local level for the application of customary rules because most of the individuals who are responsible for the implementation of the WUAs are answerable to state institutions such as DWS and district municipalities. Hence, if new water management institutions do not engage with traditional governance systems, these new institutions are likely to marginalise and replace these customary systems which contribute to water resource management objectives. The repercussions of this could be negative for marginalised villagers who are more acquainted with indigenous knowledge systems and customary laws found within traditional governance systems. Importantly, as Kapfudzaruwa and Sowman (2009) claim, traditional leaders are still playing an important role in their communities mainly with respect to conflict resolution and land allocation. Given that decisions regarding access to and use of land are integrally linked to water allocation systems, an understanding of these traditional systems should contribute to a more integrated and relevant management system. Kapfudzaruwa and Sowman (2009) make the critical observation that traditional management systems may also be effectively used for water management because they are localised (e.g. chiefs and headmen) as compared to conventional systems which require many more resources to penetrate to the local level.

Traditional management systems may be effectively used for water management because they are localised as compared to conventional systems which require many more resources to penetrate to the local level

This is critical as the new legal framework in South Africa focuses on redressing the inequalities of the past by involving users in water resource management and reforming procedures for allocating water (Schreiner et al., 2004). It provides an enabling framework for contributing to poverty alleviation and can be regarded as a tool to enhance social and environmental justice (Schreiner et al., 2004; Van Koppen et al., 2002).

As an example, Kapfudzawura and Sowman (2009) state that one traditional leader in the Eastern Cape province has delegated tasks to each household to monitor and preserve the fountain the community uses for deriving water. The families clear the pond by removing mud, which prevents pollution from entering the water resource and going into the groundwater resource.

2.1.12.1 Case study one: tole of traditional leadership in water governance, Limpopo (Tapela, 2015)

There are no customary rules established to govern the use of springs in Makuleke village. This village is situated in the Thulamela Local Municipality in Vhembe District, Limpopo Province (Tapela, 2015). The only existing rule is that adults should accompany children to the spring for safety and contamination control purposes (Tapela, 2015). This case study showed that the Makuleke traditional leadership has put governing rules and structures in place such as water point committees to monitor the condition of the spring and regulate use by community members. According to Tapela (2015), Chief Makuleke has used his power and authority to ensure that available groundwater is shared equally and conserved given the prevailing problem of potable water scarcity in the country

There are no legally binding roles of tribal chiefs in groundwater monitoring. However, tribal roles do play minimal roles in groundwater management by allowing researchers and DWS monitoring teams onto their land/villages to access the wells or boreholes; as well as the informal rules around water resources.[7]

[7] In the case of CISMOL and POPLUC it was essential to 'legitimize' our project activities and to this end we consulted with tribal authorities in the Hout to obtain permission to engage with monitoring teams and access wells and boreholes on tribal land

2.1.12.2 Case study two: role of traditional leadership in water governance, Limpopo (Tapela, 2015)

Another example is the case of the Phetwane Community; which is situated along the Olifants/Lepelle River in Elias Motswadi Local Municipality, Great Sekhukhune District in the Limpopo Province. The roles played by Chief Matlala include governance of access to water resources through the chief's control over land resources as informed by customary law. The headman is responsible for reporting any problems related to the utilisation of land and associated water resources to the chief. The Phetwane irrigation scheme was established in the 1960s, and the chief has played an important role in its governance. During the 1960s the chief used Permission to Occupy (PTO) certificates to allocate land plots in the irrigation scheme to early settlers. However, the repeal of the 1936 Native Trust and Land Act in 1991 rendered the PTOs invalid, this frustrated the elderly farmers. The Communal Land Rights Act of 2004 converted 'older order rights' into 'new order rights' which meant that land rights through PTOs were still secure, this frustrated the youth in the village as they wanted the elderly farmers who were mostly females to be removed from the irrigation scheme. The chief intervened on behalf of the elderly by utilisation of his authority of control over land and involvement in the irrigation scheme. A WUA model was adopted and included all key stakeholders and local water users; this WUA was informed by customary governance practices of the Phetwane community. The roles of traditional leadership in water resources governance in the WUA continued to spread to other water resources related areas within this community. The roles of traditional leaders are more geared towards mediation of major conflicts; mobilising the community during times of disaster, such as prolonged water shortage and disease outbreaks

The Capricorn District Municipality (CDM) of Limpopo Province has implemented a partnership through its District Traditional Leaders Forum (DTLF). The Executive Mayor of the Capricorn District Municipality is quoted as saying:

> "over the year, working hand-in-glove with traditional authorities, we have preoccupied ourselves with service delivery in the communities. This partnership (between tribal authorities and municipality) is currently working in this district, since traditional leaders have been delegated the power for the operation and maintenance of water schemes, for example (Capricorn District Municipality, 2009)."

With the subsequent colonisation of different African states by European powers African societies were traumatised by the impact of European policies and practices. Several values and practices that were dear to Africans and which had been practised for centuries had to be sacrificed. It must be pointed out that some of the main obstacles towards change in Africa

have come from the customary society and, in particular from the institution of traditional leadership. This led to the portrayal of traditional leaders as enemies of change and democracy and in some instances led to their total elimination (Mechlem, 2016). Customary laws have their own approaches to ownership issues. Customary regimes in many parts of the world regard groundwater resources as belonging to the community and reject the concept of individual rights over water. In much of Africa and Asia, customary water rights are intrinsically linked to land and embedded in land tenure. Formal water legislation might provide for the recognition of customary water rights. Unfortunately, a large number of water laws protect customary water rights but do not provide the necessary details on the interface between customary and statutory rights, thereby creating legal uncertainty as to their de facto status and protection.

Groundwater quantity and quality protection are interrelated. Poorly performed drilling operations, inadequate well construction and maintenance, and poor well-casing may result in contamination from the well or inter-aquifer leakage and groundwater degradation by mixing water from different aquifers/layers of aquifers of different quality. Therefore, the government has an obligation to identify the role of traditional leaders stated in section 212 of the Constitution. As is clear from the discussion thus far, the role of the institution of traditional leadership is not to usurp the role of government, but to complement and support government in improving the quality of life of rural communities.

The White Paper on Traditional Leadership and Governance (2003) reminds traditional leadership that they should, amongst other things promote sound relationships between themselves and others spheres of government, and act in partnership with municipalities by creating good relationships in order to enhance service delivery. Section 211 of the Constitution provides that the institution, status and role of traditional leadership, according to customary law, are recognised, subject to the Constitution, and that a traditional authority that observes a system of customary law may function subject to any applicable legislation and customs, including amendments thereto.

The requirement of the provision of Traditional Leadership and Governance Framework Act, 2003 (Act 41 of 2003) stipulates that there must be a partnership between municipalities and traditional leadership structures. The interpretation of this could suggest that some bureaucrats are still embedded in the traditional way of operating – where traditional leaders should be approached first and approve documents, etc. before these are processed by the 'modern' bureaucrats. This could further imply that there is a silent recognition that traditional leaders have an influence on the way public administration operates (Stephan et al., 2019).

Part Three: How water is monitored (rules and regulations)

3.1 How water is monitored in South Africa

Water in South Africa is monitored from boreholes (groundwater) and dams, rivers, lakes, ponds (surface water). This is done to monitor authorised activities that affect the water; such activities include water usage, waste management, and potential polluting activities. The objective of monitoring is to determine the impact anthropogenic and natural activities have on water, and to control these activities in accordance with the water management objectives and regulations (Ravenscroft and Murray, 2004). According to Ravenscroft and Murray, 2004, the four types of monitoring networks as stated by the Department of Water and Sanitation are:

- Reference (natural conditions): this is done to determine the status of natural conditions, ambient trends and surface-groundwater interactions
- Regulatory monitoring (compliance): this is done to determine how authorised anthropogenic activities, such as mining, agriculture and industrial activities affect water resources
- Specific purpose monitoring (research): research institutions and universities carry out this type of monitoring to understand groundwater flow, chemistry and surface-groundwater interactions. The purpose of this monitoring is to fill in data gaps needed for creating models required for monitoring pollution and so forth
- Early warning and surveillance: the sole purpose of this monitoring is to provide information for emergency responses. For example, when there is an accidental pollution spill that may affect drinking water supply; droughts and flooding events

Water in general is monitored by regular recording of data on water levels in rivers, dams, lakes, spring wells and boreholes to check whether the quantity has increased or decreased. Water samples are also collected from these water sources to check the quality through chemical analysis. Potential pollutants are also monitored to check their impact on the water, for example, wastewater disposal. Furthermore, rainfall impacts on the quality and quantity of water are monitored by checking water levels and quality and comparing them against rainfall rates and amounts.

3.1.2 How groundwater is monitored in South Africa

Groundwater monitoring is done through collecting the following data (SADC-GMI, 2019):

- Borehole water levels: this is done to establish whether the aquifer is being over pumped by measuring the water levels in boreholes using a dip meter (image two below). The dip meter has a metallic rod attached to the end of a measuring tape. The dip meter is dropped into a borehole, when the metallic rod encounters water it makes a sound; the monitoring personnel will then read the number on the measuring tape, which reflects the depth of groundwater (level at which groundwater is encountered)

Photo credit: K. Thwala, 2019

Figure 5: A dip meter for groundwater monitoring

- Groundwater abstraction rate: abstraction rates are measured with a flow-meter, or by recording the discharge rate and the number of hours pumped per day. This is done to relate abstraction to water levels; and the accuracy of flow-meters is verified by regular manual flow readings using a stopwatch and container
- Groundwater quality: chemical sampling is done to assess if any contaminants have entered the aquifer. Chemical parameters, such as salinity, nitrate, fluoride, alkalinity; as well as physical parameters, such as pH, electrical conductivity are checked during and compared against National Standards for water quality in different uses
- Potential pollutants data: this is done to look out for and report on potential contamination sources, such as oil spills, petroleum and petrol that could potentially change the chemistry of groundwater

- Rainfall: data from the nearest rain gauge station is compared to water levels and water quality to check the effect of climate change and whether events, such as floods or droughts on the quality and quantity of groundwater

Furthermore, groundwater is monitored manually or with automatic data loggers (see image three below). These data loggers are used to measure groundwater levels, quality parameters such as, Total Dissolved Solids (TDS), Electrical Conductivity (EC), temperature, pH and abstraction and spring discharge (SADC-GMI, 2019). These monitoring data collected by the data loggers can be downloaded from a device connected to loggers through the relevant software.

Photo credit: K. Thwala, 2019

Figure 6: A data logger for groundwater monitoring

In South Africa, approximately 2.500 monitoring points are used to monitor groundwater levels (IGRAC, 2013). Furthermore, monitoring at these points comprises electronic real time data and manual measurement of parameters with, at some points, this being still done every three months. In addition, sampling takes place twice a year (end of dry and wet seasons) at the 350 chemical monitoring points across the country; wherein analyses of macro elements, trace elements and environmental isotopes are done on the samples. The National Groundwater Archive (NGA) is used to store groundwater monitoring data; this is a centralized web enabled database, which is accessible to interested parties (IGRAC, 2013). However, NGA is not the only database; Water Use Authorisation Registration Management System and Hydstra are also used to store groundwater monitoring data (Pietersen and Beekman, 2016). South Africa has a unit called the Groundwater Resource Assessment and Monitoring (GRAM), which is responsible for assessing groundwater quantity and quality. The GRAM is also responsible for developing

protection requirements to support groundwater resource management. It allows for the generation of groundwater level maps that show annual, seasonal and monthly groundwater changes. According to Pietersen and Beekman (2016), South Africa is the country that has made progress on its groundwater-monitoring network in the SADC region although there are still challenges faced.

3.1.3 Linear (mis) representation

The following schema shows a linear model of interdependencies that we contest in our adoption of actor network theory (discussion to follow) which shows a far 'messier' interpretation than the schema offered below. Nonetheless, at first glance, this schema is helpful in presenting the legal frameworks and system of governance for water resources management in South Africa.

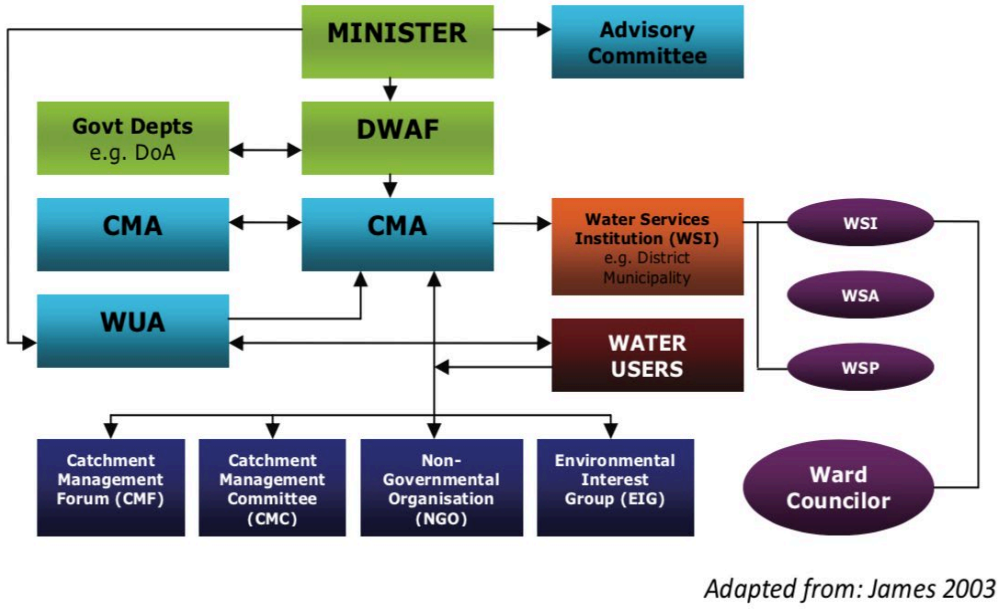


Figure 7: Overview of water management institutions in South Africa

3.2 Overview of water-related laws

The National Water Act (NWA) brought groundwater into the public domain and has enabled the DWS to effectively implement the groundwater quality management strategy (DWAF, 2000; Kelbe and Rawlins, 2004). When the NWA came into effect in 1998, groundwater lost its status as private water and became public water (Kelbe and Rawlins, 2004; Riemann et al., 2011). The NWA provides for water management through national, regional and local authorities:

- National authority: the Minister in the Department of Water and Sanitation (DWS)
- Regional authority: Catchment Management Agencies (CMA)
- Local authority: Irrigation Boards (IBs), Water User Associations (WUAs), Water Services Authority (WSA) and Water Services Provider (WSP)

In the past, groundwater had not featured prominently as a major water resource. Consequently, nearly all national control was directed at surface water resources. Several additional laws have played an important role in supporting the implementation of groundwater management strategies as enabled by the National Water Act, 1998. The water-related laws consider surface and groundwater as one entity. However, the NWA and Water Services Act (WSA) make provision for groundwater by mentioning words that are related to groundwater resources. The NWA does not specifically define groundwater but it recognizes groundwater as an integral part of the hydrological cycle as it contributes to rivers, lakes, wetlands and estuaries (Kelbe and Rawlins, 2004).

National Water Act, 1998: the purpose of this Act is to ascertain that protection, use, development, conservation, management and control of the nation's water resources is carried out in ways that are environmentally sustainable for social and economic benefits. The National Water Act of 1998 is the Act that deals with monitoring of water resources – including groundwater. This Act (National Water Act, 1998, Chapter 14) allows for the establishment of national monitoring systems and information systems that deal with surface and groundwater monitoring, floods and droughts to allow for better management of water resources through availability of information. In the absence of CMAs, the DWS takes on the function as a proto-CMA (standing in for the CMA).

Water Services Act, 1997: this Act focuses on providing water supply and sanitation services to support life and personal hygiene. The main objective of this Act is to provide water services while promoting effective water resource management.

National Environmental Management Act, 1998: the purpose of this Act is to provide for cooperative environmental governance and enforcement of other environmental management laws. This Act defines the environment as air, sea, water and land. Therefore, it applies to water management and governance.

Mineral and Petroleum Resources Development Act 28, 2002: the purpose of this Act is to regulate the prospecting, exploitation, processing and utilisation of minerals. It allows for the issuing of directives that limit any damage of the surface of land, environment or water resources.

3.2.1 Institutions and acts that deal with groundwater monitoring

To recap, we focus on the fact that South Africa has limited groundwater resources and these limited resources are extensively used in the rural areas and areas experiencing more aridity. The large-scale abstraction for irrigation across the country has put pressure on the groundwater resources. Furthermore, mining, agricultural, domestic and industrial activities have contaminated this precious resource. Therefore, monitoring systems are essential, especially since the dependency on groundwater resources has increased and continues to increase across the country as surface water resources are exploited to their full capacity. SADC (2019) states that monitoring of the state of groundwater resources focusing on quantity and quality, interaction with other components of the water cycle (surface water, rainfall and evaporation), relationship with socio-economic activities and environmental issues, is an integral part of groundwater management. IGRAC (2013) defined groundwater monitoring as the scientifically designed, continuing measure and observation of the groundwater situation, whilst SADC (2019) defines groundwater monitoring as the continuous measurement of variables such as groundwater levels, quality or abstraction to assess the status and trends. Groundwater management in South Africa is a matter of national priority; therefore, all water users have to take part in monitoring and management strategies. Institutions that deal with groundwater monitoring vary from international, national, regional to local spheres; and these include:

- International sphere: Lesotho Highlands Project, Permanent Water Commission between South Africa and Namibia, Joint Water Commission with Swaziland, Trans-Caledon Tunnel Authority (TCTA).
- National sphere: Department of Water and Sanitation
- Regional sphere: Catchment Management Agencies (CMA)
- Local sphere: Water User Associations, Water Boards, Water Services Authority Water Services Providers and Tribal Authorities

In addition, research institutions, such as the Water Research Commission and Council for Geoscience carry out groundwater monitoring to some degree, for research purposes.

3.2.2 Roles of different stakeholders in groundwater monitoring

3.2.2.1 Role of National government

The national government has the responsibility to protect, use, develop, conserve, manage and control water resources in a sustainable manner, for the benefit of all (Pietersen et al., 2012). This involves developing policies, strategies and guidelines for effective management of groundwater resources. According to Pietersen et al. (2012), the national government through the DWS has provided a national policy and regulatory framework for management of water resources by regional and local institutions. The national government (DWS) is responsible for groundwater monitoring and information in the country (ibid.). Through the DWS, the national government has developed guidelines for groundwater monitoring, siting and drilling of new monitoring boreholes; and the responsibilities are delegated to regional offices, CMAs and WUAs. The national government has also formulated standards such as the South African National Standard (SANS) which stipulates parameter limits that are used to assess the quality of groundwater.

National government is responsible for training and capacity building initiatives that involve all the relevant authorities in relation to groundwater monitoring. This level of government has enabled the DWS to implement and manage the database for storing groundwater monitoring data, known as the National Groundwater Archive. Pietersen et al. (2012) clarify that the national government, through Treasury, provides funding for DWS head and regional offices for groundwater monitoring, data capture, as well as installation, operation and maintenance of groundwater infrastructure.

3.2.2.2 Role of Unions[8]

Unions that are involved with water resources management in the country and on the African continent as a whole include the European Union (EU) and African Union (AU). The EU has undertaken commitments to accelerate the progress in the management of water resources, which is crucial in achieving the Millennium Development Goals (MDGs) (Ravenscroft and Murray, 2004). The AU endorsed the framework for the action plan on measures that will ensure that the African continent confronts economic growth challenges, environmental, poverty reduction and social development imperatives (NEPAD, 2003). This action plan is focused on dealing with problems of pollution, forests and plant genetic resources, freshwater (surface and

[8] We have included local level unions here although we acknowledge that the role of unions at the larger scale (such as the AU) differ considerably from local level unions such as NAFU or/and AFASA

groundwater), capacity building and technology (NEPAD, 2003). The European and African Unions have funded a number of initiatives for awareness, capacity building and training aimed at groundwater management on the African continent alongside other economic growth and environmental challenges that the continent faces.

Closer to home, Agricultural and Farmers' Unions, such as the National African Farmers Union (NAFU) and (AFASA) and the African Farmers Association (AFASA), play important roles in the management of water resources. The farmers become members of local farmers' associations which are affiliated to a provincial agricultural union; which in turn is affiliated to Agri SA at the national level. Agri SA changed its name from the South African Agricultural Union and is an apex organisation that acts as a mouthpiece for all farmers at the national level. The farmers' associations deal with local matters, whilst the provincial unions make Agri SA aware of the challenges faced by the farmers (Agricultural Digest, 2005/2006). The Water Affairs and Environmental Affairs functional areas of Agri SA deal with water related matters, including but not limited to:

- Fostering close working relationships with the DWS and other role-players in the water use governance and management sector
- Advising on water use entitlement position in South Africa (water use licences, general authorisations, existing lawful water uses and Schedule 1 water uses)
- Participating in raw negotiations surrounding: National Water and Sanitation Master Plan; National Water Resource Strategy; Proposed legislative amendments to the National Water Act and Water Services Act

3.2.2.3 Role of District and Local Municipalities

With the new dispensation all areas in South Africa were declared to be under municipalities. Section 151 (subsection1) of the Constitution of the Republic of South Africa, 1996, on Local Government provides that the local sphere of government consists of municipalities, which must be established for the whole of the territory of the Republic. The demarcation of municipalities and the 2000 municipal elections ushered in the new local government system. A controversy arises, however, because the new municipalities cover the whole country, including rural areas under the jurisdiction of traditional leaders.

Pietersen et al. (2012) state that municipalities are responsible for planning and developing water services and infrastructures to ensure acceptable minimum levels of provision to their

citizens. These authors remind us that the management of local water sources is the responsibility of the municipalities. A study by Ajoge (2018) on using citizens for monitoring groundwater levels on the West Coast, showed that municipalities use groundwater to supplement surface water on a regular basis. The focus of municipalities on groundwater resources is to develop these resources for abstraction. However, as Ajoge (2018) states, groundwater management is rarely directly mentioned in development plans. Furthermore, municipalities are only involved in monitoring when the sole purpose is to access the available groundwater. Groundwater monitoring is only conducted by municipalities to obtain baseline measurements before siting a well or borehole; and there are no records of continued monitoring for most of the boreholes until there are low yields (*ibid.*). According to Pietersen et al. (2012), municipalities collect groundwater data and retain it for internal use but seem to be unaware of the requirement for wider distribution. The involvement of municipalities in groundwater monitoring is limited because the roles of the municipality representatives in groundwater management are often limited to the development of groundwater resources and authorisation (Ajoge, 2018). We see therefore, that the role and duties of municipalities in groundwater monitoring have been unclear. Spurred on by the need to better understand groundwater management, the WRC funded a project to develop a Groundwater Management Framework (WRC Report No. 1917/1/10) incorporating all aspects of groundwater management at the municipal level (Riemann et al., 2011).

The following table presents legislation pertaining to water in general and groundwater in particular.

Table 2: Legislation relevant for groundwater management

Legislation pertaining to water in general	Legislation pertaining to groundwater in particular	Sections	Words mentioned
1. National Water Act, 1998	National Water Act, 1998	Section 1 (xxvii), Section 21 (j), Section 24, Section 29 (e) (iii), Section 37 (d) and Section 139 (c)	Aquifer, water found underground, borehole, groundwater
2. Water Services Act, 1997	Water Services Act, 1997	Section 1 (xxiv)	Pump installation and borehole
3. National Environmental Management Act 107 of 1998			
4. The Mineral and Petroleum Resources Development Act of 2002			
5. Environment Conservation Act, 1989			

Institutions responsible for the implementation of this legislation around groundwater monitoring, include DMRE and DFFE (provincial environmental departments).

3.2.3 Water Research Commission groundwater management framework

It was in 2016 that the WRC developed a groundwater management framework for municipalities. The aim of the framework was to help authorities improve the management of water resources in municipalities. The framework requires four management functions which are:

- Planning, deciding what needs to be done and creating a plan for action. Organising, implementing what has been planned making use of resources to carry out the plan successfully
- Leading/directing determining what needs to be done and getting people to do it
- Controlling/monitoring and checking progress which may be modified based on feedback
- Adopting of the Integrated Water Resource Management framework, in South Africa

According to this framework, municipalities are responsible for operation and for tasks that include infrastructure maintenance, cleaning and descaling pipes, replacing worn-out components, cleaning of boreholes, checking the operation of switchgear and so forth. The

municipalities are also responsible for groundwater level and quality monitoring to help in groundwater management. According to Riemann et al. (2011), municipalities are allowed to register and control boreholes and water use as stipulated by municipal by-laws.

The aim of the Groundwater Management Framework is to improve groundwater resource management by equipping the relevant municipal authorities with the required tools and capacity (*ibid.*). This framework gives a detailed description of the different functions, the relevant responsibilities, required skills, the optimal position within the municipal structure and required communication lines. It has been suggested that the framework should be implemented in KwaZulu-Natal, North West, Eastern Cape, Limpopo and Northern Cape provinces since most rural communities from these provinces derive their water from groundwater sources.

This further positions citizens (community) at the most important point of effective monitoring of groundwater levels. This is important to ensuring that groundwater is governed through a bottom-up approach, whereby groundwater resource is managed at a local level where groundwater resides, is used and can be best managed. This sets the frame for citizens to be acknowledged as citizen scientists and further demands that they participate collaboratively with other stakeholders such as the DWS, municipalities and consultants amongst others.

3.2.4 Tribal authorities and water concerns[9]

80% of those living in Sekhukhune support traditional authorities

According to Kapfudzaruwa and Sowman (2009), historically South African traditional leaders had the responsibility to manage water resources in their rural communities. However, this responsibility has been diminished with the change in government. Traditional leaders now have the responsibility of mediating conflicts and allocating land and as we know, land and water are inseparable. The responsibilities of traditional leaders are informed by cultural practices and customary rules (*ibid.*). Furthermore, the authority and powers of tribal chiefs in terms of water management are not catered for by legislation; although the South African Constitution (Sections 211-212) recognizes the existence of traditional leaders. Kapfudzaruwa and Sowman

[9] See also section 2.1.12 above

(2009) state that the traditional leaders are not legally obligated to partake in management activities and decisions regarding the management of water resources.

Tribal chiefs conduct community meeting that serve as a platform for distributing information about general issues affecting the community (Kapfudzaruwa and Sowman, 2009). Through these meetings, the tribal chiefs are made aware of the community water needs and are able to pass on the message to the relevant authorities. Kapfudzaruwa and Sowman (2009) remind us that cultural and religious practices are still practiced in the villages. These practices include baptism and initiation ceremonies conducted in rivers that WUAs are also using to access raw water (*ibid.*). These cultural and religious practices pollute the water that is used for irrigation and sometimes drinking purposes downstream. With the consideration of surface water-groundwater interaction, any impacts on either one of the water resources will certainly affect the quantity and quality of the other resource component (Fleckenstein et al., 2010). Therefore, this means that over-use of rivers and springs, as well as pollution of these water sites by villagers will affect the quality and quantity of groundwater. According to Kapfudzawura and Sowman (2009), villages have informal rules relating to community taps aimed at monitoring and combating the groundwater pollution problem and excessive use of water.

Traditional leadership is not unique to South Africa – many countries in the world have various forms of hereditary leadership and absolute monarchies

In Western Europe, countries like the United Kingdom, Spain, Holland, Sweden, Norway, the essential nature of the systems of traditional rule was abolished and replaced with democratic governance systems, although rudimentary elements of the institution still remain. In the United Kingdom, the monarchy, headed by the Queen, still plays a significant role in national affairs (Mechlem, 2016).

And in concluding the section on traditional authorities, picking up from our discussion in 2.1.12 above, we are reminded of the African proverb *kgosi ke kgosi ka batho* – a chief is a chief through the people. The delivery of public goods requires leadership, management and good governance that are defined by accountability. The concept of leadership in broad terms refers to a commitment to making the world a better place for others.

The concept of leadership in broad terms refers to a commitment to making the world a better place for others

The business of delivering public value and goods has on most occasions been associated with government. But then again, it emerges that quality products and services in the course of the delivery of public goods is attributable to the partnerships that the government enters into with the other players. As our discussion in part two of the report has claimed, traditional leadership and or traditional authority comes across as another indispensable partner in the delivery of services more especially in the rural parts or areas of the country, traditional leaders do play an important role in the processes and course of delivering services to the rural communities in the country (Matshabaphala, 2017).

We will consider the theoretical concepts in part two but in the meanwhile, we would like to present a visual idea – perhaps better revisited in the figures that follow on meshwork, yarning and entanglement that are messier and more realistic – of the polycentric aspect of governance that we have discussed above. As a starting point this captures the multiple centres of decision making, rules, regulations and realities that have been covered in some detail above. As the discussion below unfolds, we develop our ideas of polycentricity, pluralism and citizen science and clearly this figure below that identifies different actors (different coloured 'dots'), still very much in connecting 'lines,' such as the private sector, government bodies, non-profit organisations, becomes messier and more puzzling as we proceed.

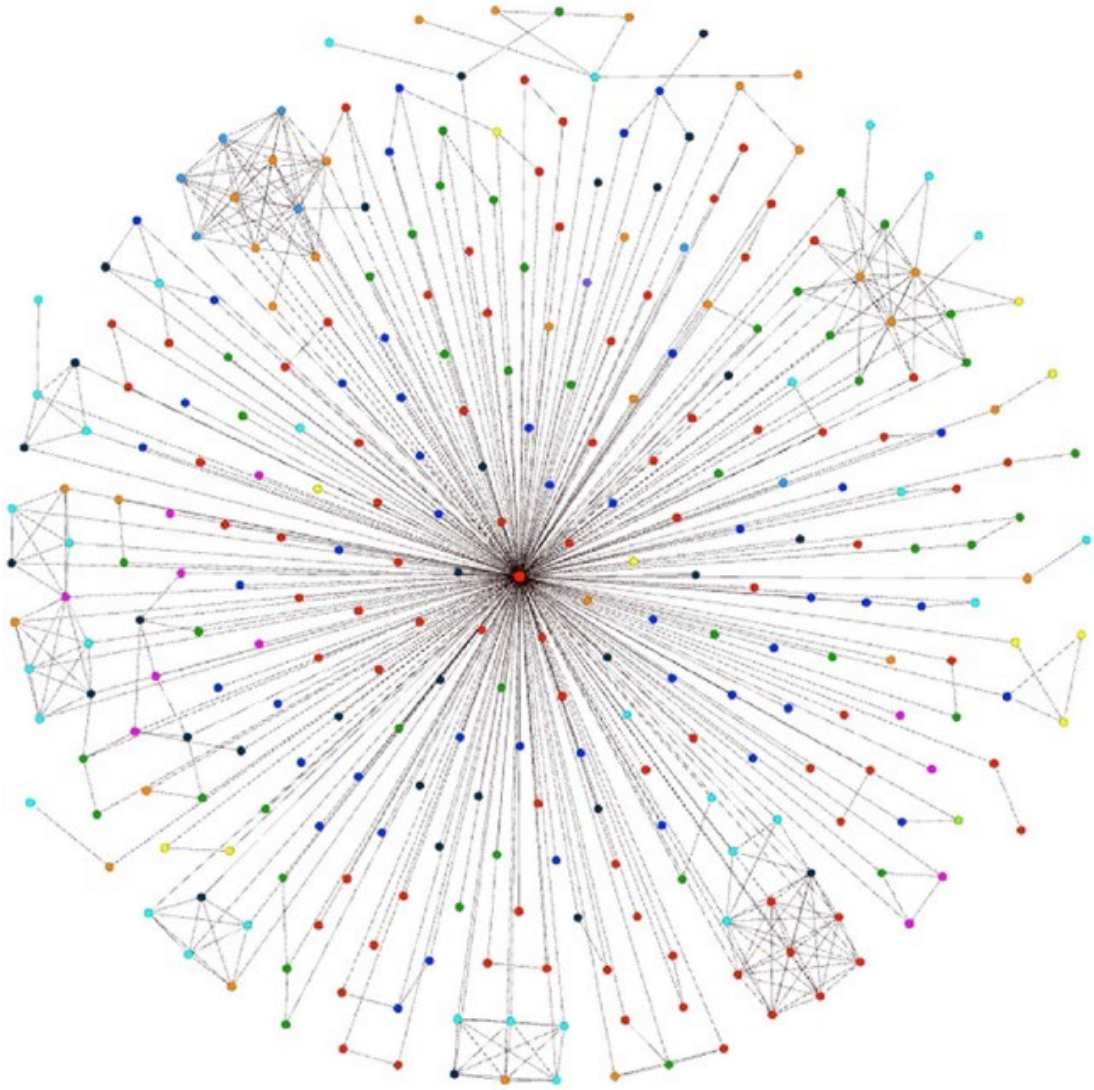


Figure 8: Recognising polycentricity

Part Four: Concepts of nexus, citizen science, pluralism and polycentricity

4.1 Conceptual framework

A conceptual framework is an analytical tool that is used to obtain a comprehensive understanding of a phenomenon. It can be used in different fields of work and is most commonly used to visually explain the key concepts or variables and the relationships between them that need to be studied.[10] It is not merely a collection of concepts but, rather, a construct in which each concept plays an integral role (Jabareen, 2009). A conceptual framework can be seen as a network, or "a plane," of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena. The concepts that constitute a conceptual framework support one another, articulate their respective phenomena, and establish a framework-specific philosophy (ibid).

The relevant concepts playing this integral role for the POPLUC frame are 1) nexus 2) citizen science 3) pluralism and 4) polycentricity. In elaborating on each of these concepts it becomes clear that together they provide an innovative and critical framework for POPLUC in general and in particular working in the confines of water resources management (WRM) – in this case groundwater monitoring. As we turn to this theoretical (conceptual) understanding we are reminded of the following extract:

> "There is not, and never will be, a best theory. Theory is our chronologically inadequate attempt to come to terms with the infinite complexity of the real world. Our quest should be for improved theory, not best theory, and for theory that is relevant to the issues of our time (Walsham, 1997:478)."

Theory is our chronologically inadequate attempt to come to terms with the infinite complexity of the real world

[10] Wikipedia definition

4.2 Nexus approach to groundwater monitoring

The word nexus comes from the Latin word *nectare* which means to connect (Liu et al., 2018). Nexus refers to approaches that address linkages between multiple distinct entities (ibid). The nexus approach stems from the realisation that water, energy, agriculture and natural ecosystems exhibit strong interlinkages and that under a traditional sectoral approach, attempting to achieve resource security independently often endangers sustainability and security in one or more of the other sectors. Under the nexus concept, connections, synergies and trade-offs are analysed and understood. According to Liu et al. (2018), the nexus concept has long been used in philosophy, cell biology and economics and was first used in the natural resource realm in 1983 under the Food-Energy Nexus Programme. Since then, it has been used most frequently to study food, water and energy connections. [11]

As Liu et al. (2018) proclaim, many global challenges, though interconnected, have been addressed singly, at times reducing one problem while exacerbating others. Nexus approaches simultaneously examine interactions among multiple sectors. Recent quantitative studies have shown that nexus approaches can uncover synergies and detect trade-offs among sectors. If well implemented, nexus approaches have the potential to reduce negative surprises and promote integrated planning, management and governance. These authors also remind us that this approach is sometimes applied to issues, such as biodiversity protection and human health, or within specific framings such as responding to climate change.

The nexus approach to environmental resources management considers interrelatedness and interdependencies of environmental resources and their transitions and fluxes across spatial scales and within and between different compartments. In this way, instead of just looking at individual components, the functioning, productivity, and management of a complex system are taken into consideration. The resource nexus concept has been increasingly discussed in engineering, natural and social sciences, resulting in the existence of manifold understandings and uses. While a basic understanding of the concept exists and is widely used in research and practice, the concept is hardly operationalised. According to the United Nations University (institute for integrated management of material fluxes and of resources), this hinders the

[11] See also GWP (Global Water Partnerships), n.d. *The Nexus Approach: an introduction-GWP*. Available at: https://www.gwp.org/en/GWP-Mediterranean/WE-ACT/Programmes-per-theme/Water-Food-Energy-Nexus/the-nexus-approach-an-introduction/

analysis of the conditions (e.g. participation, governance) and effects (e.g. sustainability) of implementing a nexus approach for the sustainable management of environmental resources.

According to the Global Water Partnership (GWP), a nexus approach is important in groundwater management because water plays a key role in generating energy; and energy is required to process and distribute water, to treat wastewater, to pump groundwater and to desalinate seawater. Water is also the keystone for agriculture and the food supply chain. An example of why a nexus approach is needed for groundwater management is India, wherein the hotspot for groundwater depletion coincided with the states of Rajasthan, Punjab and Haryana that benefited from the Green Revolution (Mukherji, 2020). The Green Revolution brought about subsidized electricity policy, easy availability of credit for constructing groundwater wells and buying pumps, and food procurement policies that guaranteed procurement of rice and wheat crops, which aided in eradicating poverty and hunger in these states (ibid).

We argue in this current project (POPLUC) that a nexus approach is needed in managing and governing natural resources such as land, water and energy to improve environmental, climate, human and political security. But we also argue that citizen science, pluralism and polycentricity complement each other as concepts and provide a more rich narrative when considered together rather than separately. As such, the three concepts, polycentricity, pluralism and citizen science add value to a study on groundwater and its complex socio-political, environmental and geographical landscape.

4.3 Introduction to citizen science (CS)

Over the past decade, an exciting trend has been recorded worldwide, with thousands of lay people from, in, and across different countries becoming engaged in citizen science (CS) projects, through various modes and channels of collecting, commenting, transcribing and analysing data (Tauginienė et al., 2020). However, CS has been predominantly pursued within the realms of the natural sciences (Crain et al., 2014). Activities and projects following social sciences and humanities (SSH) topics and approaches are less easily discernible in CS practice, although they may be fuelled by some genuine and challenging questions (Heiss and Matthes, 2017). A survey of CS projects in Europe revealed that more than 80% of current CS practice is confined to life and natural sciences and only 11% to the social sciences and humanities (Hecker et al., 2014).

80% of current citizen science practice is confined to the life and natural sciences with only 11% to the social sciences and humanities

The underrepresentation of SSH may be due to several reasons. One of them is the stable and long-lasting bonds between CS and the natural sciences, with pioneer lay scientists mainly directing their interest towards the study of physical and natural phenomena by making use of positivistic methods of data collection and analysis (Tauginiene et al., 2020).

Also, a fundamental transition has occurred in recent decades from "traditional" science to something new – leading to the much-cited book *The New Production of Knowledge – the Dynamics of Science and Research in Contemporary Societies* which claims fundamental changes in the ways in which scientific, social and cultural knowledge is produced (Gibbons, 1994). The 'new production of knowledge' is already two decades 'old' and yet the struggle to foster scientific literacy in the public domain continues. Citizen science over the past decades, is very much part of this new struggle for the production of knowledge – generating expertise, fostering scientific literacy, and enhancing learning through engagement in all scientific disciplines but, as we will have already stated, with a concentration on the natural sciences (Frigerio et al., 2021).

According to Bhattacharjee (2005) studying large-scale patterns in nature requires a large amount of data to be collected across various locations and habitats over spans of years or even decades. And one way to get such data is through citizen science, a research technique that involves the public in gathering scientific information. This kind of approach for data collection requires inclusive engagement and participation amongst professionals and general participants.

The central role of CS in many disciplines of academic research has been acknowledged by the Citizen Science Alliance (CSA)[12] which has almost 2 million volunteers. As the founder of the CSA, Chris Lintott (2019) claims, we can no longer indulge in the twentieth-century habit of leaving science to the scientists, but in area after area we are finding that we must instead all pitch in. CS has been widely discussed and explored amongst scientists, policy makers and planners, because it allows for genuine interactive and inclusive science engagement. In the

[12] www.zooniverse.org

water sector this is of particular relevance because of the integrated water resources management (IWRM) regime, that dominated water resources discourse from the Dublin days in the 1990s right through to 2020. The main premise of IWRM was to achieve social equity, financial viability and environmental sustainability through managing the resource close to its point of use and, critically, by adopting participatory processes with ordinary citizens who depended on the resource when making any decision that might affect their lives.

A reflection on the application of CS across disciplines is helpful. Some of the longest-running CS records in the world are from Japan. For example, the timing of cherry blossoms has been recorded in Kyoto for 1200 years, so long that they have been used in climate reconstructions (Aono and Kazui, 2008). Centuries-long phenology data also exist for other plant and animal species across Japan (Primack et al., 2009). The study of Ivan and Margary (1926) is also pertinent as it reports how many centuries ago, in 1736, Robert Marsham started recording 27 phenological events, such as first flowering, leafing and the appearance of migratory birds, for more than 20 common plant and animal species in his family estates in Norfolk. An impactful example is the work of the Entomological Society Krefeld, where the work of citizen scientists over the course of nearly three decades allowed tracing a 75% decline in biomass (Hallmann et al., 2017). The Zooniverse gives people of all ages and backgrounds the chance to participate in real research with over 50 active online CS projects such as SONYC which is one such project, based at New York University who are developing a smart citizen sensor network with machine listening capabilities to identify and mitigate the sources of noise pollution in New York City. Another is Snapshot Serengeti which involves cameras tracking the movement of thousands upon thousands of animals migrating with and following the wildebeest. SciStarter monitors active and non-complete projects and according to this source, there are currently more than 1500 CS projects globally that are registered and are active. From these 1500 projects about 200 are CS projects that are practiced in Africa.[13]

As Newman et al. (2012) argue, the future of CS will likely be inextricably linked to emerging technologies. By spanning multiple spatial, temporal, and social scales and by being designed to achieve a number of different outcomes, CS projects will need to adopt new technologies to allow participants and organizers to communicate and interact effectively (Newman et al.,

[13] There is no exact number of recorded CS projects in the Republic of South Africa (RSA) but many projects are being implemented through 1) CSIR – Council for Scientific and Industrial Research 2) SANSA – S.A National Space Agency 3) SANBI – S.A National Biodiversity Institute 4) CREW – Custodian of Rare and Endangered Wildflowers 5) iNaturalist 6) rePhotoSA 7) Cape Citizen Science 8) MiniSASS project which is available on www.wrc.org.za report TT763/18 by Mark Graham and Jim Taylor and their team in KZN

2012; Kobori et al., 2016). The educational aspect underpins the volunteer experience and in the case of our project, literacy about groundwater is empowering and although encouraging citizen participation in data collection and analysis, we see it is primarily a means of meaningful education and has an emancipatory and transformative potential (see section 4.4.10).

The educational aspect underpins citizen science and literacy about groundwater is empowering – it is primarily a means of education with emancipatory and transformative potential

Data obtained not just in one well but in many wells in a catchment, heightens awareness of the downstream/upstream movement of water but also enhances feelings of belonging and of being anchored in a watershed, embedded alongside others who also depend on the resource for their well-being.

Nowatny (2003) refers to the dilemma of expertise as proposed by Plato who lashes out against the distortions and the irrationality that characterises the formation of public opinion and the articulation of political will among the 'mob'. And yet as Nowatny reminds us the modern 'agora' (meeting place) can hardly be said to be populated by the 'mob' as it is populated (as in our case) by highly articulate, and never before so well-educated a population. The incorporation of science into the modern agora – therefore – is an expression of confidence in its potentiality. Certainly we confirm high quality data that has been validated and verified and a highly water literate generation of citizen scientists engaged with groundwater monitoring in the Hout.

4.3.1 CS and the Sustainable Development Goals (SDGs)

The United Nations Secretary-General's synthesis report on the Post-2015 Development Agenda proposed one universal and transformative agenda for sustainable development, underpinned by rights and with people and the planet at the centre (UN, 2014). In September 2015, the United Nations 2030 Agenda for Sustainable Development, which consists of 17 Sustainable Development Goals (SDGs), was ratified. This Agenda provides a framework upon which governments can implement policies and actions towards achieving these goals by 2030. The SDGs cover many areas including, among others, poverty, food security, energy, health and

well-being, inequality, gender, production and consumption, urbanization and numerous environmental issues affecting land and marine ecosystems as well as climate change (Fritz et al., 2019). Our CS project relates to several of the SDGs, in particular but not only, Goal 6 'Clean Water and Sanitation'. Strengthening global collaborations in implementation is the subject of goal 17. Goal 5 is also significant, calling for gender equality. As with the Millennium Development Goals (MDGs), the UN's Post-2015 SDGs will only be achieved with the active engagement of volunteers. Volunteer contributions to sustainable development are distinctive. Volunteers' close engagement with communities in need, their skills and motivation to contribute to more inclusive, active and cohesive societies, and modelling/facilitation of the reciprocal exchange of knowledge and skills among stakeholders, make volunteers distinctive actors in support of the achievement of the SDGs (Haddock and Devereux, 2016). Volunteerism is at the core of CS and it implies that individuals give time without pay to activities performed either through an organization or directly for others outside their own household or related family members. We consider two categories of volunteers – the first refers to (informal) volunteering outside the context of an organisation. These volunteers that operate outside the context of an organisational setting, sometimes called "helping" or "neighbouring," are thought to be the major share of volunteer activity in many countries (Salamon et al. in Haddock and Devereux, 2016) and it is this "helping" or "neighbouring" aspect of volunteerism that guides and informs CS within the context of the ESGUSA Phase 1 project, the previous WRC project and this current WRC project.

The 17 SDGs endorsed by late September 2015 are intended to transform our world by addressing the social, economic and environmental challenges faced by the global community – with all countries and stakeholders acting in collaborative partnership. Most relevant within the context of CS and the role of volunteers in monitoring wells, rivers and rainfall are SDGs 5, 10, 16 and 17. Goal 16 promotes peaceful and inclusive societies, providing access to justice for all and building effective, accountable and inclusive institutions at all levels. Goal 17 aims to strengthen the means of implementation and revitalise the global partnership for sustainable development. These goals provide an opportunity to demonstrate the strong value-added that volunteerism brings as an integrating mechanism that helps people and institutions better connect in partnerships of mutual benefit, allowing synergies or complementarity towards common goals/targets and indicators. Additionally, SDG Goal 10, to reduce inequality, is particularly pertinent to many volunteer groups and might be considered a priority, with the democratisation of knowledge and with it the power to make decisions and better understand their environment.

SDG 10 to reduce inequality is particularly pertinent to citizen science and could be considered a priority – with the democratization of knowledge and with it the power to make decisions and better understand their environment

4.3.2 Science and society

CS provides a way to be interdisciplinary both within the university and across university departments and within and across departments in government. It permits the validation and classification of huge datasets that would otherwise be unmanageable. One tends to think of community science efforts as being isolated to small-scale tracking of local issues but this is not so as these grassroots efforts are now becoming networked to tackle widespread issues of social and environmental justice as well as questions about effective conservation practices. CS holds the potential for developing new ways to collectively solve big problems and to fundamentally change the relationship between science and society. Within the WRC and ESGUSA project we consider CS to be an approach whereby non-scientists are actively involved, to differing degrees, in the generation of new scientific knowledge, from which they also actively stand to benefit either intrinsically (e.g. increased scientific literacy) or extrinsically (e.g. increased social capital and improved well-being). Alan Irwin (1995) sought to reclaim two dimensions of the relationship between citizens and science: 1) that science should be responsive to citizens' concerns and needs; and 2) that citizens themselves could produce reliable scientific knowledge.

Haklay et al. (2021) in their article entitled 'Contours of citizen science: a vignette study' note the proliferation of definitions and typologies. The authors also concede the challenges of reaching consensus about a definition and that plurality is far more realistic given the diverse disciplinary lenses that are being applied. Wehn and Almomani (2019) refer to the new roles involving citizens in data collection as community-based monitoring (CBM) and information systems, also seen to be citizen observatories. Wehn et al. (2021) also reflect on the many forms, definitions and meanings of CS, reminding us that while some definitions focus more on citizen science as a tool for collection and analysis of data (e.g. Oxford English Dictionary 2014), "others define it as a multi-stakeholder process that aims at increasing democratization of science and policy, scientific citizenship, public engagement, transparency, equity, inclusiveness and justice" (Wehn et al., 2021:1). In defining CS it is also helpful to consider the work of The European Citizen Science Association (ECSA) who identified 10 core principles that

define Citizen Science.[14] Building on these ideas, we put forward a simple definition which is citizen science is taking science out of the laboratory into life.

4.3.3 Trust and Citizen Science

One of the most critical ingredients in the application of citizen science is trust. We consider the way in which trust can be nurtured within different geographical settings – in this case between sections one, two and three of the Hout Catchment. Trust has a social and political geography as well as a geography of place. We consider trust to be an essential ingredient for building networks and linkages (social capital),[15] both horizontally (between the volunteers themselves) and vertically – between volunteers, municipalities, tribal authorities, research team, government departments such as DWS. Trust is an outcome of a successful CS project. It is the glue that keeps the project going (Goldin, 2010).

Trust is the glue that keeps our project going, it is not a 'nice to have' but a 'must have' – it determines social action

Trust is not just 'nice to have' but is a 'must have' because it determines social action – engagement or disengagement as the case might be. It allows for the establishment of solidarities between water users, volunteers, research team members, private sector, donors and government. Trust is also closely related to legitimacy, because legitimacy requires participants to see the process as fundamentally fair (Bryson et al., 2006; Emerson and Nabatchi, 2015). Legitimacy is also enhanced when participants with interdependent interests are able to pool resources to improve their joint capacity for action (Emerson and Nabatchi, 2015).

It is pertinent to draw on the work of the well-known expert Ostrom (1996) who isolates three properties of social capital that are relevant for the CS component of this WRC project.

- It does not wear out with use but rather with disuse
- It is not easy to observe and measure
- It is hard to construct through external interventions

[14] https://ecsa.citizen-science.net/documents/

[15] See Granovetter (1973) and Goldin (2003) and Goldin (2010)

Trust is a set of behaviours, such as acting in ways that volunteers and others depend on one another. Trust is a belief in a probability that a person will behave in certain ways (predictability and reliance). Trust is also an abstract mental attitude toward a proposition that someone is dependable and there is a feeling of confidence and security that others with whom one is interacting, care.

The concept (social capital) refers to various social factors that contribute to well-being, although these factors are often elusive. When considering social action and engagement/disengagement, we prefer the term meshwork, which we take up in some details in our discussion below, to the idea of social capital (with its financial implications). We have seen in our own work how meshwork can have both positive and negative attributes because it can inhibit collective action and stand in the way of reform. In other words – segments of society (such as the commercial farmers, or small-scale farmers) might 'stick together' and not open up their networks to build new affiliations. This is counter intuitive for the brokering of trust. We see positive aspects of meshwork – the building of trust through our series of stakeholder workshops and the eagerness to monitor groundwater in section one and three as well as the eagerness of commercial farmers – who were initially very reticent to do so – in section two to collaborate with us. We are interested here in the intangible goods that people carry in their hearts and heads (Krishna, 2002). The 'thinking' part (trust), or attitudinal aspect, predisposes people to mutually beneficial collective action and vice versa – mutually beneficial collective action can foster trust.

Citizens do not decide or behave outside a social context because they are embedded in often very fluid entanglements. We adhere to the 'rules of the game' as they are integral to our understanding of trust and 'opening doors' requires a respect and 'listening' to what is 'the right thing to do.' For instance, when forging new links with volunteers in section one and three there were 'rules' we learnt about – who to approach, how to 'open gates' and whose authority to listen to. We have discussed this in the section on tribal authorities above. The research team were aware that the building of trust would mean being privy to 'rules of the game' and game is certainly not to be taken flippantly. It is a deeply rooted set of rules that govern the commons at one level and the way in which social systems pivot around each other, protecting their own regimes whilst at the same time interlocking in an iterative way with other institutions on which they depend. These rules, in the case of section two of the catchment, were opaque and less easy to adhere to as the farmers form part of an 'old boys club' where, as members they have been negotiating trust amongst themselves for over forty years – farming and working in the particular section of the catchment. This meant that opening gates took longer, was more

sensitive, and required a careful step by step approach.[16] In all instances (section one, two and three of the catchment), these rules have most surely been established to reduce uncertainty by establishing a stable structure for human interaction. Trust is important for the practices and organizing principles that are established within and around these institutions.

The way in which the ideas match the actual is not always neat. Institutions, committees and forums are expected to have both positive and negative effects on water users and although the paradigm of IWRM supposedly meant upstream-downstream affiliations, this is not in reality always the case. There needs to be adequate and accurate information for water users to make appropriate and efficient decisions. The project of monitoring groundwater in section one, two and three of the Hout is one step towards providing adequate and accurate information that can be shared between upstream-downstream users. In the ideal, it is a contributor to trust building within catchment areas and between different sections of the catchment. It also promotes a new sense of belonging – where farmers who were isolated now are linked (through the monitoring work) to a group that extends beyond themselves.

We found in our own work, that there is an undersupply of trust where it is most needed – in other words, often existing within different segments of the catchment, but not across segments. The urgency for trust is to equalize the balance of power between government and citizens and between citizens themselves so as to produce new forms that 'yarn' together (see discussion on yarning below).

For the progressive management of water systems – including – but not only groundwater – work with citizen scientists emphasises process – CS being a long journey and not an end destination – in which differences and highly differentiated needs are acknowledged in their specificity. This means deliberately paying careful attention throughout the duration of any given project to a learning approach – ensuring no-one is left behind. Participation, inclusion/exclusion, knowledge and power are determinants of how and in what ways trust is produced and maintained – in other words more participation is likely to mean more trust, more water literacy more trust and feelings of control or power of the individual are also likely to produce higher levels of trust. As feminist thinkers, such as Nancy Fraser (2009) Iris Young (1990) or/and Bozalek et al. (2013), we too consider diversity and difference rather than universality. We take up this idea in our discussion on an ethics of care below.

[16] COVID-19 and the imposed lock down meant that visits to the field that were programmed for May and June 2020 did not take place and there is a delay in bringing commercial farmers on board

4.4 Pluralism

Pluralism is too often what Mann and Keller (2013) call a 'pale' term, suggesting an affirmation of what these authors see as 'the friendly coexistence' of different things which might be different branches of government, different ways of knowing, different fundamental moral values – or different genders, cultures, religions or sexualities. The global centre for pluralism defines this concept as a set of intentions and practices that seek to institutionalize recognition of difference and respect for diversity as civic culture. According to the Global Centre for Pluralism (2012), pluralism is a "process, not a product." In contrast to pluralism, which is a normative reaction to diversity, the global centre for pluralism considers diversity as an objective truth.

Pluralism implies difference and divergence where all participants have equal access to and opportunities for impact. According to Yumatle (2015) pluralism can be seen as a concept of social diversity, which is an interaction between conflicting and competing positions. It can be used as a cultural or political stance. The author presents pluralism as an alternative method of describing the social difference that comes from varying values and attitudes. We find the idea of pluralism most helpful when considering our work in citizen science as pluralism adds value to how social diversity is understood. The concept is formulated around the nature of diversity, on this basis it can be argued that social diversity is not gone – and pluralism is always about recognizing diversity.

Friedline (2020) thought the exact definition is open to debate and that pluralism, in the context of a liberal democracy, can be broadly understood as a system in which people of diverse religions and belief systems can coexist peacefully with, more or less, equal opportunity to share in political power. There are two separate sets of questions that political philosophers must address when discussing pluralism. The first are questions about the laws and government structures that make up pluralism as a political institution.[17] The second set of questions is addressed to citizens living in a pluralist democracy concerning how they ought to act in public life in relation to their government and their fellow citizens. These are questions about civic virtue.

[17] Here the work of Mukuyu, Van Koppen and Jacobs-Mata on Operationalising Hybrid Water Law (WRC C2019/2020-00111) is pertinent

4.4.1 Defining pluralism

There are three kinds of pluralism, cultural pluralism, political pluralism, and philosophical pluralism. Cultural pluralism refers to the diversity of cultures and their expressions of values and beliefs. Some thinkers admit to the existence of cultural pluralism and integrate it into a political arrangement and a philosophical theory about justice but abstain from asserting anything conclusive about the fundamentally pluralistic nature of values or their impact on social agency (Yumatle, 2015).

Philosophical pluralism does more than simply admit the permanent existence of social variety. It includes empirical diversity and a philosophical view about the character of values and the experience, knowledge, and awareness we have of them. According to philosophical pluralism, cultural, moral, and political diversity is an unavoidable and permanent by-product of the character of the values that comprise it, of our limited epistemological capacity, or of the historical and political construction of human experience. From a philosophical point of view social diversity is explained by value pluralism and radical pluralism (*ibid.*).

Value pluralism maintains that values are plural, conflicting and incommensurable in that they lack a single standard that can accurately measure trade-offs, are incomparable and cannot be seamlessly exchanged or collapsed into one another without residue.

Values are plural, conflicting and incommensurable – they are incomparable and cannot be seamlessly exchanged or collapsed. One value, one goal, one worldview can never account for the totality of human experience

Again, this fits well with our approach to citizen science where one principle, one value, one goal, one worldview can never account for the totality of human experience. Radical pluralism highlights the constructive, historical, and political tenor of our experience and identity, which is always varying, limited, constraining and exclusionary (Peels et al., 2019). Yumatle (2015) quotes John Rawl's (1993) book Political Liberalism, where the existence of reasonable pluralism is necessary for contemporary liberal democracies to function properly. John Rawls argues that

the concept of justice as a basic good is about the recognition of ethical and cultural heterogeneity and of its impact on the justification of a just political order.

Still thinking about value pluralism, Pascual et al. (2021) highlight the importance of understanding the various reasons why people care about conservation, for instance, and whether and in what ways this will help policymakers and conservationists formulate effective intervention plans. These authors argue that a multi-voice perspective could be used to discuss various aspects of conservation, including the needs of marginalised groups.

A multi-voice perspective could be used to discuss various aspects of conservation, including the needs of marginalized groups

Cultural and political pluralisms articulate the social difference that stems from habits, beliefs, or interests, while philosophical pluralism goes further and adds an interpretation of the origin, character, and experience of value heterogeneity on social agency (Harman, 2000). It offers a full account of the anatomy of normative difference, of its awareness, and of its impact on social agency. These three kinds of pluralism are not necessarily mutually exclusive. Philosophical pluralism always entails the acknowledgment of empirical diversity at the heart of cultural and political pluralism.

4.4.2 Pluralism as secular enchantment

This (ground)water world is plural in terms of multiple uses, multiple points around which decisions pivot – and spatial pluralism – as well as numerous levels and scales of governance that ripple through the politics and practices of water. As the discussion above suggests, pluralism is an interpretation of social diversity. It can be rendered as a cultural, political or philosophical stance. Any kind of pluralism (cultural, political, philosophical) presupposes at the very least an empirical thesis about irreducible diversity. In short, pluralism holds that social diversity and the disagreement that grows from it, are unending. The attempt to permanently quench difference misrepresents and distorts human experience (Yumatle, 2015).

Pluralism is an infusion of value in our lives – an interminable quest for ethical orientation. It is a secular form of enchantment

4.4.3 Pluralism and subjectivity

Shah's (2018) work on subjectivity and pluralism and the work of Suransky and Alma (2018) on 'agonistic learning' are pertinent when acknowledging the way in which pluralism and subjectivity infuse different knowledge regimes and multiple spheres of decision-making and governance. Subjectivities of a farmer, an engineer, a government official, a local chief are enmeshed with his/her cultural differences and modus operandi, making for confusing (dis)connects between players trying to solve, together – or in their separate ways – what is often a 'wicked' problem.

Subjectivities of a farmer, an engineer, a government official, a local chief are enmeshed with his/her cultural differences and modus operandi making for confusing (dis)connects between players

We apply the idea of meshwork at every step of the way – asking who is involved, what role they play, what are obstacles and opportunities for being involved, etc. so as to map out nodes of power, privilege, poverty and influence, scrutinising the potential for tension or conflict and the potential for enhanced collaboration.

We seek greater clarity on what polycentricity in the segments of the catchment where we are working means, and what the increasingly complex socio-cultural pluralities that Suransky and Alma (2018) identify are – such as the profile of volunteers, profile of decision-makers and the roles and responsibilities of the many different actors.

4.4.4 Pluralism and decentralisation

The term decentralization embraces a variety of concepts which must be carefully analysed before determining if projects or programs support reorganization of financial, administrative, or service delivery systems. Decentralization – the transfer of authority and responsibility for

public functions from the central government to subordinate or quasi-independent government organizations and/or the private sector – is a complex multifaceted concept. Different types of decentralization should be distinguished because they have different characteristics, policy implications, and conditions for success (Litvack et al., 1998). Global trends toward democracy and decentralization have created unprecedented opportunities for popular participation in government.

Under appropriate conditions, all of these forms of decentralization can play important roles in broadening participation in political, economic and social activities in developing countries. Where it works effectively, decentralization helps alleviate the bottlenecks in decision-making that are often caused by central government planning and control of important economic and social activities. Decentralization can help cut complex bureaucratic procedures and it can increase government officials' sensitivity to local conditions and needs. Moreover, decentralization can help national government ministries reach larger numbers of local areas with services; allow greater political representation for diverse political, ethnic, religious, and cultural groups in decision-making; and relieve top managers in central ministries of "routine" tasks to concentrate on policy.

In some countries, decentralization may create a geographical focus at the local level for coordinating national, state, provincial, district, and local programs more effectively and can provide better opportunities for participation by local residents in decision-making. Decentralization may lead to more creative, innovative and responsive programs by allowing local experimentation. It can also increase political stability and national unity by allowing citizens to better control public programs at the local level (Litvack et al., 1998).

According to Chambers (2001), decentralization means that resources and discretion are devolved, turning back the inward and upward flows of resources and people. Decentralization and empowerment enable local people to exploit the diverse complexities of their own conditions, and to adapt to rapid change. Empowerment means that people, especially poorer people, are enabled in such a way that they can take more control over their lives and secure a better livelihood with ownership and control of productive assets as one key element. In the context of chaos and complexity theory – the analogy to be explored for human society is that not centralisation and many complex rules, but decentralisation and a few simple tendencies or rules, are the conditions for complex and harmonised local behaviour (Chambers, 1997). In the light of the above, it is worth noting that the South African national water policy has embraced the concept of decentralisation in relation to the management of water resources, through the

adoption of the principle of subsidiarity. This principle is expressed in the National Water Act through the provision for management of water resources by Catchment Management Agencies at the catchment scale

Not centralization and many complex rules but decentralisation and a few simple tendencies or rules are the conditions for harmonised local behavior

4.4.5 Pluralism and water resources management

Evers et al. (2017) introduce a new concept called pluralistic water research, which aims to study the interactions between humans and water systems. Despite the increasing complexity of water related problems, the pursuit of knowledge related to water has remained a major challenge for academics and decision-makers. Hence it is important to understand the interaction of human water systems. Its social dimensions are essential to effectively tackle challenges in sustainable water management.

Due to the complexity of the interactions between humans and water systems, their management has become more complex. Growing population and urbanization modifies the demand for water resources. Water management and use is influenced by a number of factors such as economic growth, urbanisation, land-use change, hydrological-climatic changes, technological advances, history, political and to some extent traditional practices based on religious and cultural beliefs. Water-related problems are often interconnected and can only be solved by the interactions among various scientific disciplines. Understanding the social and co-evolutional dimensions of human-water systems is necessary to effectively address the shortcomings in water management (Evers et al., 2017).

4.4.6 Problematic pluralism

A large body of scientific evidence has shown that diversity may frequently hinder development. The relationship between diversity and development could be mediated by two types of mechanisms. The first set is concerned with the possibility that the development preferences of diverse communities are not shared, that diverse communities may struggle to work together to provide public goods, and/or that diverse communities may be less able to sanction each other for failing to cooperate. The second group of issues concerns the greater likelihood of conflict

(potentially violent), because of poorly managed diversity. Horizontal levels of inequality between groups as well as ethnic fractionalization have a role in a potential vicious cycle of underdevelopment and conflict (King, 2017).

Development can be hindered by diversity through two principal mechanisms which are 1) preferences, technology mechanisms and benefits of co-ethnic sanctioning what may limit the provision of public goods in ethnically diverse societies and 2) the second principal mechanism includes violent forms which may be more likely in diverse societies where there are horizontal inequalities between groups. According to King (2017) there are widely supported findings that show there is a negative relationship between diversity and public good provision, education, irrigation projects, trash collection and other community services.

4.4.7 Pluralism and polycentricity

The concept of pluralism is central to the idea of polycentricity. Pluralism refers to a society, system of government, or organization that has different groups that keep their identities while existing with other groups or a more dominant group (Wollenberg et al., 2001). Pluralism serves as a model of democracy, where different groups can voice their opinions and ideas. For example, in a pluralistic company/organisation, employees are involved in decision-making rather than having management dictating all decisions. Rather than maintaining an old-school centralized structure, employees or members are consulted and listened to regarding important decisions. This is a form of polycentricity, just at a small scale.

Plurality means in any society there are complex, overlapping and sometimes competing networks of actors, rules, functions, and organisation. For instance, Mollinga (2007) argues that water governance, management and use are characterised by three types of plurality: multiple actors and organisations involved in water decision-making at different levels; multiplicity of rules and procedures applicable to a specific issue, as in legal pluralism; and multi-functionality of water-resources systems and the range of different values attached to these functions.

4.4.8 Cultural pluralism continued

Cultural pluralism has also been the building block of discussions on ethical theory. For instance, relativism and universalism are two opposing/clashing philosophical views about the rightness and wrongness of our moral judgements. On the one hand universalists argue that cultural pluralism is not against the possibility of finding universal truths while on the other side relativists believe that cultural pluralism is evidence of both normative and meta-ethical relativism.

Chandra Kukathas (2003) argues that cultural diversity does not preclude the possibility of moral criticism or developing universal standards, nor does it make it impossible to acquire moral knowledge. Cultural pluralism, for Kukathas, does not raise a problem for moral theory, as there are fundamental commitments and shared beliefs among cultures that make moral argumentation possible. On the other hand, Harman (2000) believes that whether someone is wrong in doing something always depends on an understanding or agreement of the particular culture in question and not on basic moral demands that apply to everyone.

Whether someone is wrong in doing something always depends on an understanding or agreement of the particular culture in question and not on basic moral demands that apply to everyone

Cultural pluralism, according to Yumatle (2015), refers to the fact that cultures are expressions of a variety of values, practices, and beliefs. Cultural variation yields in turn ethical diversity. It is a sociological view about the existence of heterogeneity in practices, beliefs and value systems which may or may not turn into a philosophical position about the nature of values and our experience of them. The focus of cultural pluralism is empirical diversity manifested in values, practices, and beliefs.

Cultural pluralism can be integrated into political and philosophical theory whilst at the same time abstaining from asserting anything conclusive about the fundamentally pluralistic nature of values or their impact on social agency. Cultural pluralism does not necessarily involve a meta-ethical view about the irreducibility of plural character of values. Cultural pluralism can also be integrated into a philosophical view about modernity and the rational limits of ultimate decisions about value. Thus, cultural pluralism is accompanied by a theory of justice with a philosophical understanding of the character of values, namely that the shared understanding of the value of a social good determines its proper distribution.

4.4.9 Pluralism and power

Power is not an identifiable property that humans possess in fixed amounts. Rather, people are powerful because they control various resources. Resources are assets that can be used to 'force' others to do what one wants.

Power is not an identifiable property that humans possess in fixed amounts. People are powerful because they control various resources

Politicians become powerful because they command resources that people want or fear or respect. The list of possibilities is virtually endless: legal authority, money, prestige, skill, knowledge, charisma, legitimacy, free time, experience, celebrity, and public support. Pluralists emphasize that power is not a physical entity that individuals either have or do not have but flows from a variety of different sources.[18] However, the core concern of pluralism in political science lies in the organizational and institutional articulation of competing individual and group interests and the distribution of power. Political pluralism may or may not presuppose a philosophical view about the plural character of values and its impact on human agency.

4.4.10 Pluralism and feminist philosophy

Feminist philosophers have played an important historical role in undoing the notion that humans exist with singular universal politics, ethics, epistemology, etc. Pluralism has been used loosely and vaguely to mean a friendly coexistence of different things, from different branches of government, different ways of knowing, different fundamental moral values or different genders, cultures, religions, and sexualities (Mann and Keller, 2013). Mann and Keller (2013) also argue that it is easy to see this 'friendly coexistence of diverse things' when historical and present positions of power are not in favour of anyone. The moment a feminist philosopher, critical race theorist and philosopher of sexualities or anyone who was historically disadvantaged join the conversation the diversity becomes apparent and no longer possible to affirm pluralism because of the history of such relations and the structures of power that underwrite them (ibid).

We see our work of yarning and entanglement sitting well with thinkers such as Nancy Fraser (2009) and her work on the scales of justice and Joan Tronto (1993, 2012) on an ethic of care. Overall work on citizen science has not yet provided a theoretical frame that is explicit about equity, social justice and the human right to know.

[18] https://www1.udel.edu/htr/American/Texts/pluralism.html

Overall work on citizen science has not yet provided a theoretical frame that is explicit about equity, social justice and the human right to know

Ernst (2019, in Jadallah and Ballard, 2021), while referring to participatory processes and social learning – often applied within a CS context, echo this, identifying a scarcity of profound analytical concepts guiding empirical analysis. Jadallah and Ballard (2021) do fill this gap in their work on sociocultural learning theory. But we add to these debates by proposing that a feminist analytic lens – coupled with concepts of yarning and entanglement – brings to the fore an ethics of care with the much-needed emphasis on social justice and equity. Such an analytic frame will, we believe, add value to the work on citizen science where we are attentive to methods and participatory processes of authentic learning.

A feminist analytic lens – coupled with concepts of yarning and entanglement – brings to the fore an ethics of care with the much needed emphasis on social justice and equity

We argue that all too often citizen scientists are (mis)represented as homogenous data gatherers rather than as people who, in their specificity, express hope, self-esteem, dignity, joy and other human emotions that are often as invisible as the invisible rivers (ground water) that run under the ground. The tendency is, as we know from the work of Tanguine et al. (2020) and Goldin et al. (2021) to focus on visible data rather than invisible more intangible assets that have to do with what people carry in their hearts and heads. We see stakeholder engagement as something constantly moving, shifting and breathing and in tension with privilege, poverty and power.

A feminist pluralism is simply an affirmation of plurality as a condition for the possibility of human existence and political life. It is an affirmation that a common world is constituted in and through the active engagement of those occupying different social locations and inhabiting different points of view with one another. Pluralism in a feminist deep sense must always be power-sensitive and attuned to historical relationships of enfranchisement and

disenfranchisement, acquisition and (mis)appropriation, authorisation and de-authorization. For this reason, the idea of power, privilege and poverty is helpful.

For the philosopher of plurality, Hannah Arendt (in Mann and Keller, 2013), pluralism is one of the essential conditions of human existence. The conditions of human existence mean we are all equal, on one level but also distinct. Pluralism is then seen as two-fold as it includes both equality and distinction. Humans are then living as distinct and unique beings among equals. From this perspective then the role of plurality is to establish a common world, where the world can only exist because of plurality of individuals or peoples.

Pluralism includes both equality and distinction

The application of feminist thinkers around diversity, social justice and particularity rather than universality resonates with ideas of research integrity and the creation of a more just social setting. Citizens become technically savvy and the distinction between the professional with their technical know-how and the citizen scientist becomes far more blurred. The result overall is emancipatory for citizen scientists as they gain water literacy and are better able to manage their water resources for sustainable future use.[19]

Pluralism implies difference and divergence and the (feminist) notion of an ethics of care

4.4.11 Pluralism and redundancy

From the perspective of traditional public administration scholars, redundancy is inefficient because it introduces duplication of governance functions. The argument here is that redundancy might also undermine good governance by promoting fragmentation or causing problems with accountability (Bendor, 1985). However, considering that there are multiple levels of governance – and that authorities do overlap – it seems more helpful to accept this rather than argue for negative implications such as redundancy. Baldwin et al. (2018) also argue for resilience rather than redundancy – and that 'redundancy' might make a system more reliable

[19] In WRC project (C2020/2021-00085), CISMOL, we focus on the emancipatory and transformative aspect of citizen science where we use participatory tools such as the river or life, participatory mapping, participatory monitoring and evaluation to narrow the gap between the 'professional' and the citizen scientist

than any of its separate parts because, as Cohen and Axelrod (2000) state, it manages the risks of independent failures. Baldwin et al. (2018) illustrate this point with the image of pollinators in an ecosystem. Here pollinators include butterflies, wasps and bees. As the authors claim, each insect may prefer a particular plant species, but there will be a sufficient degree of overlap to maintain a minimal level of pollination should something happen to one of the pollinators. Similarly, in a water governance system where local resource users, regional associations and national officials – and now citizen scientists – all undertake monitoring of water use, there will be some overlap to ensure a minimal level of monitoring even if one of these actors does not fulfil its duties.

Pluralism holds that social diversity and the disagreement that grows from it are unending. The attempt to permanently quench difference misrepresents and distorts human experience

4.5 Polycentricity

Governance can be seen as a process by which the repertoire of rules, norms, and strategies that guide behaviour within a given realm of policy interactions are formed, applied, interpreted, and reformed – and in this process both government officials and non-governmental actors can play critical roles (Stephan et al., 2019). Polycentric systems are complex adaptive systems without a central authority controlling the processes and structures of the system. As such they are characterised by multiple governance units at multiple scales with each unit having some capacity to govern at its scale (Garmestani and Benson, 2013).

Cases of polycentric governance are rife with jurisdictions whose connections are either formally absent or ambiguous and confusing, often by design. This idea reverberates with the notion of meshwork and vibrant entanglement. Ultimately, polycentric governance can be understood as an intrinsically dynamic process embedded within a contingent type of structure that is difficult to capture in simple measures. And thus we consider individual pathways and 'knots' that become entangled and resist the impulse to try and join one dot to another. Rather we consider how they intertwine and mingle and where there might be unanticipated expectations and obligations.

We consider individual pathways and 'knots' that become entangled – resisting the impulse to join one dot to another – they intertwine and mingle with unanticipated expectations and obligations

Do actors adjust to each other only because they have to, once they come to realize the extent of their interdependence? Or do they mutually recognize each other's goals as legitimate concerns, and acknowledge a minimal sense of legitimacy to the actions of others? More generally, are these actors and their strategic options considered only on a one-off basis or are they connected together within a broader sense of community or legitimacy? Whether described as an 'overarching set of rules', an 'overarching set of norms and rules', or even as a 'general system of law', the concern here is whether there is a rule-based structure that manifests a shared sense of connection among these actors. In more informal terms, are they all playing the same game, according to a mutually agreed-upon set of rules for that game, or are they merely engaging with each other because they have to, but otherwise exist in a social vacuum (Stephan et al., 2019)?

Actors operate in silos, with puzzling socio-economic and legal systems around groundwater governance where there are shifting allegiances as we adjust to the polycentric, pluralistic nature of meshing government systems and entangled socio-political environments. Relevant to the work on groundwater monitoring, and as Buytaert et al. (2014) claim, polycentric monitoring may challenge the monopoly on data held by hydrometeorological departments in many countries and may therefore encounter resistance.

The concept of pluralism is central to ideas of polycentricity. As is clear from our discussion thus far, pluralism implies difference and divergence and the (feminist) notion of an ethics of care where all participants have equal access to and opportunities for impact. Greater clarity is needed around what polycentricity means in practice, in particular what capacity exists for actors at different scales and levels within a watershed to take genuinely autonomous decisions. As scholars have begun to explore multilevel approaches to natural resource governance, many have become interested in polycentricity – defined here as an approach to governance in which multiple, autonomous decision centres share overlapping responsibility within a particular policy area (Aligica and Tarko, 2012; Stephan et al., 2019).

At the core of the definition of polycentricity is the idea of multiple centres of decision-making – the concept of pluralism is central to ideas of polycentricity

4.5.1 Background to polycentric systems

Being less streamlined than tightly integrated centralized systems, polycentric systems tend to 'enhance innovation, learning, adaptation, trustworthiness, levels of cooperation of participants and the achievement of more effective, equitable and sustainable outcomes at multiple scales' (Ostrom, 2010:552). Critical to the original definition put forward by Ostrom et al. (1961) was the notion that the decision-making centres were formally independent of each other and no single centre had ultimate authority over others. All centres retain significant autonomy from any other centre. From the earliest days of conceptualizing polycentric governance systems there has been an understanding that multiple decision-making centres take each other into account to some extent. They do so by engaging in regularized forms of interaction, which might take the form of competition, (mis)co-ordination, contractual relationships, consolidation, and other instruments for collective action. Different decision centres can compete, and thus be interdependent, with little awareness of each other. Whether described as an 'overarching set of rules', an 'overarching set of norms and rules' or even as a 'general system of law' the concern here is whether there is a rule-based structure that manifests a shared sense of connection among these different actors (Stephan et al., 2019). In line with our ideas behind yarning and entanglement, we emphasise that this might be dis-connection rather than connection.

Polycentricity has roots in the biological and chemical sciences and in the redistributed process of decision-making in scientific communities. The term polycentric or monocentric was used to describe the different kinds of plants in botany when it comes to their reproductive cells. The term polycentricity is still used in botanical studies to describe the type of plants whether they have multiple reproductive cells or single reproductive cells (Stephan et al., 2019). Take the conceptual leap from an organism with many reproductive centres to societal arrangements with many decision centres having limited and autonomous prerogatives and operating under an overarching set of rules (Aligica and Tarko, 2012).

Although there is no single definition of polycentricity, the concept generally suggests multiple, autonomous decision centres that have overlapping authority over geographic areas, policy areas or aspects of governance. Polycentricity was first described four decades ago as an approach to governance by Ostrom et al. (1961). According to these authors, the concept of polycentricity was first introduced to political science and public administration literature within the context of cities within the United States to make sense of how most metropolitan areas in the United States do not have a single dominant political leader but have many public local authorities. People living and working in the city are provided with a wide range of public services and the public services are more efficiently delivered at different levels of spatial aggregation.

Stephan et al. (2019) understand polycentricity as an adjective that modifies the noun governance. The traditional pattern of government in a metropolitan area with multiple political jurisdictions may be perceived as a polycentric system. Polycentricity refers to conditions where a pluralistic organisational structure reflects a pattern of power and influence characterised by many interdependent but relatively autonomous organisation units (Stephan et al., 2019). The concept of polycentricity is often used to describe the various inter-related disciplines and economic markets. Within the political sphere, federalism is often considered the most prominent example of this concept. The formation of relationships among public agencies operating at local and national levels as well as organisations that are not really considered political such as neighbourhood associations, inter-state compacts, community councils, fire protection, schools and water resource management, involves numerous governments at different levels and different levels of decision making. This complexity leads to the formation of polycentric governance. Complexity is more likely to make overly central arrangements unresponsive to localised public interest. Stephan et al. (2019) gives an example of when a centralised approach was taken, it may take two-three years to respond to improvements of a sidewalk or a particular aspect of urban infrastructure, even when local residents have undertaken the costs. A central system is likely to be less responsive to the 'smaller' details, such as having a sidewalk repaired. A polycentric political system can be viewed as an alternative to the unresponsiveness that often occurs when decisions are made at the level of the public.

4.5.2 Defining polycentricity

One can observe that at the core of almost all definitions of polycentric governance are multiple centres of decision-making, multiple authorities and no one has the ultimate power to make decisions. Based on the example from Stephan et al. (2019) mentioned above, decision making

and service provision units are likely to vary in size since not all public goods are efficiently produced at the same level of aggregation. The concept of polycentricity has various definitions and is often used as a political concept. A polycentric law is a theory of legal structure that states that a given jurisdiction has a monopoly on certain types of legal services. Instead of being bound by a single law, these services may be offered by various providers (Buytaert et al., 2014).

Polycentric governance is about governance that has polycentric attributes, where governance is a process by which the repertoire of rules, norms, and strategies that guide behaviour within a given realm of policy interactions are formed, applied, interpreted and reformed (Stephan et al., 2019). Thus, we confirm that at the core of almost every definition of polycentric governance (or polycentricity, polycentric systems or polycentric arrangements) is the idea of multiple centres of decision making – or multiple authorities, no one of which has ultimate authority for making all collective decisions. The specific features of these multiple centres are rarely delineated.

4.5.3 Polycentricity and water resource management

Buytaert et al. (2014) claim that the new progressing approach to a hydro-meteorological monitoring landscape (science/citizen) is dominated by national networks with a more diverse community of multilevel and multipurpose monitoring. It shows a strong resemblance to the emerging academic insight that water management in certain circumstances may benefit from a polycentric governance model. Polycentric models show strong links with river basin management and governance. The model acknowledges the multi centres of decision-making within a catchment and provides a potential alternative to the top-down centralizing tendencies through 'new' claims for integrated water resources management. Ostrom (2010) states that the landscape of hydrometeorological monitoring is dominated by networks of a diverse community of multilevel and purpose monitoring participants.

We noted how Baldwin et al. (2018) have used the metaphor to illustrate an ecosystem in which pollinators include butterflies, wasps and bees. Each insect may prefer a particular plant species, but there will be a sufficient degree of overlap to maintain a minimal level of pollination should something happen to one of the pollinators. Similarly, in a water governance system where local resource users, regional associations and national officials all undertake monitoring of water use, there will be some overlap to ensure a minimal level of monitoring even if one of these actors does not fulfil its duties.

4.5.4 Polycentricity and institutional complexity

The management of natural resources poses immense challenges as we are confronting not simply the physical reality of invisible 'rivers' that move betwixt and between political borders. Mimicking this image of invisibility, there are multi-layered inter-sectoral realities that jigsaw back and forth, for instance, between departments such as the Department of Water and Sanitation, Agriculture, Environmental Affairs, Tourism, Health, Education, Social Development and local structures (chiefs, counsellors), municipalities, ordinary citizens and research team members. Sometimes a focus on community and local management can happen in a way that simplifies and idealizes local knowledge and ideas behind community and tradition (Roth et al., 2015).

And yet, the field is fraught with challenges based on the fact that there is a lack of common understanding, for instance – but not only – on what role traditional leaders should play in local governments and other spheres (Bank and Southall, 2013). This is the situation, despite the fact (that we have presented above) that the study by Oomen (2007) shows that 80% of those interviewed in the Sekhukhune (Limpopo Province) supported traditional leadership (Stephan et al., 2019). Chieftaincy is viewed as a strong political force at the local level, for instance at the level of district municipality (see section 3.1.6.4 above); and this is evident by the way in which even government officials pushed community members to follow traditional protocol, in order to be assisted (Ntsebenza, 2011).

In addition, cases of polycentric governance are rife with jurisdictions whose connections are either formally absent or ambiguous and confusing. Polycentric governance spill over effects can occur between jurisdictions, regardless of overlap.

4.5.5 Polycentricity as meshwork

We begin by presenting the more traditional idea of 'connecting' different players and that is actor network theory. Today, networks proliferate to an astonishing extent. We are told that we are living in a network society (Castells, 1996, 2000). Technical networks, such as those of the internet and other kinds of virtual communication, are said to surround us. It is also claimed that businesses and organizations are organized along network lines. Network analysis began as a method which straddled the two disciplines of anthropology and sociology (Knox et al., 2006).

For many, the word 'social' is used to show the world as being invariably split up (a priori) into two separate halves: a social half, consisting of humans; and a natural-material half, consisting of things. In this sense, human beings (subjects) are seen as the primary agents of a social world, and 'social' is what occurs when meanings and representations are passed from person to person. Consequently, elements of the natural-material world (objects) are ignored, or reduced to their symbolic representations.

The word 'social' is used to show the world as being split up: a social half, consisting of human; and a natural-material half, consisting of things. Elements of the natural-material world (objects) are ignored

In line with Durkheim (and also Marx or Max Weber) these 'natural' forces are supposed to impinge upon and determine the actions of individual subjects. Here, 'social' is meant to stand apart from other concepts, such as: 'individual,' 'physical,' 'natural' and 'material.' Thus, 'social' is what is left over after these other elements are filtered out. Consequently, plants, animals and material and discursive artefacts are either ignored or treated as passive and deemed irrelevant for sociological inquiry. However, as Dolwick (2009) claims, it is about adding nonhumans to sociological and anthropological studies to form an actor network.[20] Furthermore, actors are relationally linked with one another in webs or networks. They make a difference to each other. And all in all, they make each other be (Dolwick, 2009).

4.5.6 Social as association

But this does not mean that actual physical-material things are 'necessary,' or even particularly important for human social action. Durkheim merely presents us with a one-sided view of the world/universe, where the human species acts 'on' things, but not with, through, or in response to them. And what both Weber (in the first half of this century) and Marx (towards the latter half of the last century) have in common is their lack of interest in things. And now, over the past few decades, we need to ask the question how does one fit artefacts, indeed all kinds of things, into depictions of 'social' (Dolwick, 2009)? In perhaps its broadest sense, social means association.

[20] Within actor network theory, an actor (actant) may be anything: an insect, a boat, a person, a government, the unconscious, a virus, etc. (Dolwick, 2009)

This is after the Latin word socius, meaning a companion or associate (ibid). When it is used this way, the meaning of the concept is left open to include anything and everything that may be associated together. Thus, social (connections, interactions) may include plants, animals and material artefacts as well as human.

In its broadest sense social means association. This means that social may include plants, animals and material artefacts (also things such as laws and legislation) as well as human

No actor has complete control over a state of affairs. Anyone who has ever locked their keys out of the car while it is still running, or struggled to build something without proper tools, or tried to organise an event around the weather and ten other people's schedules, will know exactly what this means: a number of little things may matter and make a difference (Dolwick, 2009).

The concept of the social network has proved to be a powerful analytical tool and influential metaphor for understanding the interconnected nature of human social relations since the early twentieth century (Knox et al., 2006; Mitchell, 1974). Like other terms such as 'agency', the everyday usage of the term 'network' brings with it a variety of different understandings and assumptions. However, at its heart, the network centres on the interconnections and interdependencies that lie between persons, places and things (Giddens, 2015). Traditionally, social network analysis (SNA) displays these networks graphically as points (or nodes, representing the individuals within the network) and lines (or links, symbolising the social interaction(s) that occur between these individuals). Treated as closed systems, SNA uses graph theory and other mathematical approaches to measure these sociometric features of interpersonal networks, quantifying their overall connectedness and dispersal from the perspective of an individual (ego-centric) and for the network as a whole (global or whole). Researchers go on to use these graphs to explore the flow of information or resources within the network, often associating this with political control or influence. Popularly referred to many decades ago by Granovetter (1973) as 'the strength of weak links,' this key insight highlighted the need to understand the extended network, appreciating the varying degrees of connection that can link people. Social network analysts appreciate that the connections linking people together extend endlessly in time and space.

In the 1990s, Latour proclaimed that actor-network theory was – then – the most popular means of examining the relationship between technical and social relations (Latour, 1990). Actor network theory proposes that it is not simply individual (society) but also things, material entities, that determine the nature of the network. This idea is elaborated on by Bruno Latour (1993, 2005). For instance, his book *Reassembling the Social* provides an example – for instance a lecturer in a lecture theatre is influenced by the architect who designed the theatre, by the podium and so forth – this brings attention to materiality. Having said that, actor-network theory does offer two key insights that have influenced a wider audience. To begin with, ANT has highlighted the importance of non-human entities and objects, either by the agencies of others through time and space or as transformative agencies in their own right. ANT provides a vocabulary to examine how powerful networks emerge and pays particular attention to assemblage and the influence of objects and people (Carroll et al., 2012).

ANT also offers an alternative perspective on the issue of scale. In this view, there is no 'global', merely action loci that have greater concentrations of connections to other action loci. Ethnographic research by authors such as Busby and Strathern has highlighted the significance of social relations in establishing identity and, in some cases, defining personal attributes such as gender (Giddens, 2015).

Geographic data is a sub-set of information that represents some features, attributes and objects of the world; typically it includes both physical (e.g. land cover, soil type) and socio-economic (e.g. land use, soil capability) facets. The manner in which features of the world are identified as being of interest (worthy and capable of being mapped), and organised varies from application-to-application, institution-to-institution and country-to-country (Comber et al., 2002). A network is often described in terms of nodes and links. In ANT the nodes are actors, and an actor is any entity that interacts with other actors or serves as an intermediary between actors. As stressed, ANT accepts humans and non-humans (objects) as actors, since all interactions between humans are mediated through objects of one type or another. In ANT the links are the interactions between actors sometimes termed the "translations" (Latour, 1987 in Comber et al., 2002). The approach is to determine the interactions, connections and activities of actors involved. Even for small activities the possible number and dimension of all potential interactions (from strong to weak) of actors (human and non-human) at any particular point in time (as networks evolve) is very large (Comber et al., 2002). The links between actors have to be mapped in order to be able to elucidate the networks and structures. This can be done in many ways, but the key is to ensure that the dynamics of the actor-networks are adequately represented (*ibid.*). ANT approaches scientific endeavour from a socio-logical perspective.

Networks describe people and institutions, artefacts and entities that have different spheres of influence including the design of the new technology, its diffusion and its operation.

ANT is a theoretical orientation based on relational ontology. It originated in science and technology studies in the early 1980s and has from the start been preoccupied with the ways in which societal order is achieved and the role material elements and other nonhumans play in that process. ANT enriches our theoretical and empirical understandings of social phenomena, beyond its familiar domains in science and technology. This contrasts sharply with the active presence of ANT and ANT-influenced ethnographies in anthropology, geography, urban studies, and cultural studies (Farias and Bender, 2010). These studies, no matter how interesting, concern themselves with the social relations of individual human actors – their frequency, distribution, homogeneity, proximity. In contrast we are now not limiting ourselves to human individual actors but extending the word actor – or actant – to non-human, non-individual entities (Latour, 2005).

More precisely it is a change of topology. Instead of thinking in terms of surfaces – two dimension – or spheres – three dimension – one is asked to think in terms of nodes that have as many dimensions as they have connections. As a first approximation, the claim is that modern societies cannot be described without recognizing them as having a fibrous, thread-like, wiry, stringy, ropy, capillary character that is never captured by the notions of levels, layers, territories, spheres, categories, structure, systems (Latour, 1993, 2005).

Far/close: the first advantage of thinking in terms of networks is that we get rid of "the tyranny of distance" or proximity; elements which are close when disconnected may be infinitely remote if their connections are analysed; conversely, elements which would appear as infinitely distant may be close when their connections are brought back into the picture. I can be one metre away from someone in the next telephone booth, and be nevertheless more closely connected to my mother 6000 miles away; an Alaskan reindeer might be ten metres away from another one and they might be nevertheless cut off by a pipeline of 800 miles that make their mating for ever impossible; my son may sit at school with a young Arab of his age but in spite of this close proximity in first grade they might drift apart in worlds that become at later grades incommensurable; a gas pipe may lie in the ground close to a cable television glass fibre and nearby a sewage pipe, and each of them will nevertheless continuously ignore the parallel worlds lying around them (Latour, 1993, 2005).

I can be one metre away from someone in the next telephone booth and be nevertheless more close to my mother 6000 miles away

It is worth considering what networking is not: the word actor has been open to the same misunderstanding as the word network. "Actor" in the Anglo-Saxon tradition is always a human intentional individual actor and is most often contrasted with mere "behaviour." If one adds this definition of an actor to the social definition of a network then the bottom of misunderstanding is reached: an individual human – usually male – who wishes to grab power makes a network of allies and extends his power – doing some "networking" or "liaising" as Americans say. This is alas the way ANT is most often represented which is about as accurate as saying that the night sky is black because the astrophysicists' have shown there is a big black hole in it (Latour, 1993, 2005).

4.6. Actor Network Theory and Meshing

As Latour notes, "we never leave the local level" as social interaction happens within particular and ever-shifting locations of action (Latour, 1993: 121). At the same time he also tells us that "no place dominates enough to be global and no place is self-contained enough to be local;" as a result, any search of a mediating force between the two is meaningless (Latour, 2005: 204). All of this brings us closer to the idea of meshwork. We also move from the assumption that there is social homogeneity to an appreciation of the degree of variation at both a local and regional scale. We increasingly acknowledge a heterogeneous collection of overlapping social groups and identities which operate on multiple scales – and in multiple localities. To encounter someone or something is to be open to learning from them and the relations they are composed of.

Meshwork explains more the entanglement of individuals – full of loose ends and always on the move (Klenk, 2018). In a world of life – knotting is the fundamental principle of coherence. It is the way forms are held together and kept in place within what would otherwise be formless … thus conceived, knotting is about how contrary forces of tension and friction, as in pulling tight, are generative of new forms (Ingold, 2015).

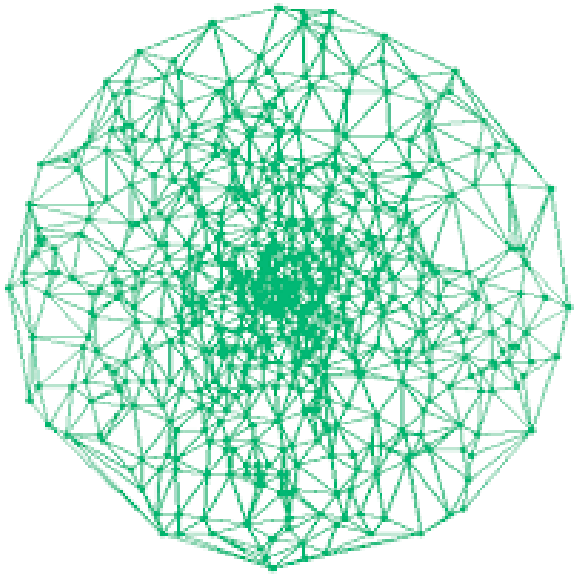


Figure 8: Meshwork one [Klenk, 2018]

In this section we illustrate how the meshwork metaphor can give transdisciplinary theory and practice more breathing space for difference. The meshwork metaphor describes research practices that are more responsive to the unique pattern of relations that are encountered during research. A meshwork metaphor can help explain how individuals and knowledges are entanglements that emerge through encounters with others. Critiques of society emphasise that they are not closely bound but rather porous, fluid, surprising and vibrant. As Giddens (2015) claims, these meshworks allow plurality without requiring uniformity, strengthened in part by the tensions and contradictory currents that exist between its member constituents.

As such, meshwork-thinking may provide an appropriate framework (and broad-based methodology) for exploring the social relations within the diverse context of the catchment. Social landscape emerges from the everyday interactions between people, places and things as they carry on their lives. This concentration on embodied living (through the taskscape[21] and the maintenance of interpersonal networks, respectively) brings to focus the intimate scales of social relations (Ingold, 2000). Importantly, our social networks (meshworks), contain both the animate and the inanimate. This is very different from our thinking of static – or linear – network linkages. Both Latour and Ingold see our social collectives (including personhood) as being dynamic and unstable, in and of themselves – what Ingold describes as in a constant state of 'becoming.' Furthermore, once emerged, these entities develop their own capacities to act and

[21] In 1993 Ingold introduced the idea of 'taskscape' to explain how places and landscapes emerge through the activities of 'those who dwell therein'

inter-act, thus engaging with others to form new networks and assemblages at ever greater scales.

Such meshworks are dynamic, unbounded and in possession of emergent properties and capacities. As such, they reflect the fluid constitution of social interaction within the real world (Giddens, 2015). For our study, what is important is the way in which meshwork resonates with ideas of plurality, as meshworks permit plurality without requiring uniformity, strengthened in part by the tensions and contradictory currents that exist between its member constituents. Networks may be dynamic, but meshworks are growing, moving forward and evolving with each engagement. In addition, as embedded meshworks themselves, the actors (or actants) who participate within these higher order assemblages change, develop and grow as a result of these constitutive connections. As such, these meshworks are boundless and scalar, extending in both time and space. By their nature, these meshworks are comprehensive, incorporating a myriad of agents, both human and non-human, in the constitution and reification of social life (Giddens, 2015).

Our social meshworks contain both the animate and inanimate. The goal in this endeavour is not to establish (linear) causation but to describe the complex and general sense of embeddedness inherent in the constitution of the 'social' landscape

Hodder's (2012) idea of entanglement is helpful. As such, it offers an alternative to more traditional descriptions of social relations that continue to emphasise rigid social structures and/or default to universal normative rules and practices. Also, by defining the emergence – and maintenance – of larger-scaled social collectives through the mutual engagement of others, it provides a means to explore the inter-play between different scales of interaction. Tim Ingold (2000) in his book *Perception of the Environment*, merges the philosophical arguments of Heidegger with ethnographic data from traditional hunter-gatherer groups, he argues that the subject is not born preformed as a bounded entity.

Subjectivity is created through everyday interaction with other persons, animals, objects and places as each make their way through the world. In this meshwork individual entities interact and pull apart only to meet up again in the future

These lines of meshwork represent the "the trails along which life is lived" rather than the 'connectors' that traditional social networks depict (Ingold, 2007). There is an interactivity with others (as we have noted this is both animate and inanimate) which takes place within 'the taskscape' (as reflected in image seven for instance) which is the amalgamation of individual tasks carried out within the course of daily life and through which the wider landscape derives meaning. By focusing on the lived life, a more realistic rendering of the idea of meshwork starts with circles that then entangle and enmesh (see image seven below).

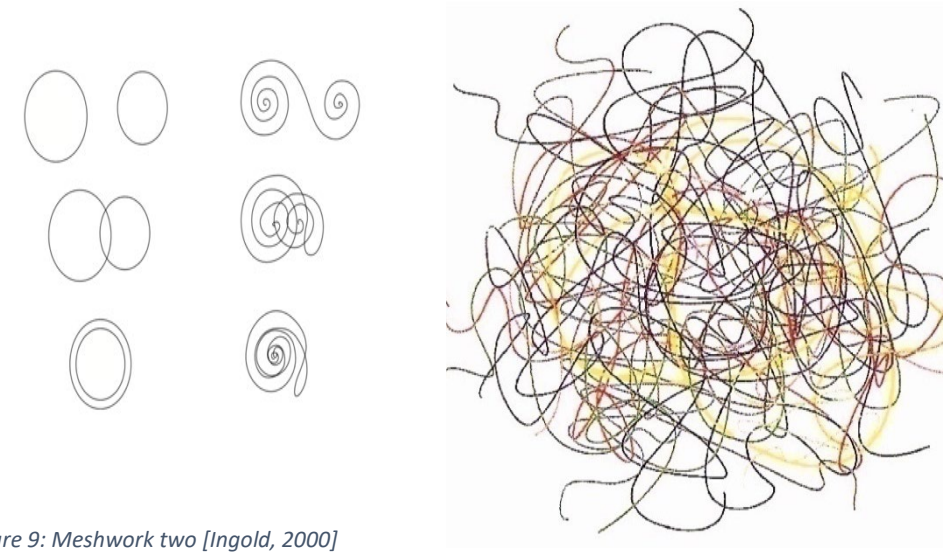


Figure 9: Meshwork two [Ingold, 2000]

4.6.1 Assemblages

Delanda (2006) argues that social reality is comprised of a variety of intermediately scaled entities, or social "assemblages." These assemblages emerge from the interaction of smaller scale components, who may in turn be assemblages themselves (DeLanda, 2006: 32-4).

Social assemblages both constrain and empower – capacities of the whole create opportunities and risks for its components

Whilst this model of increasingly larger (or smaller) scaled assemblages may resemble the nested hierarchy of the Russian doll, DeLanda is keen to stress that social reality is far more complex; individual social entities (seen either as interpersonal networks or institutional structures) can be a component of multiple assemblages, resulting in significant overlap. These social assemblages both constrain and empower their underlying parts; in other words, the capacities of the whole create opportunities and risks for its components.

Also pertinent here is the idea of yarning – from the verb 'to yarn' which means to tell a story – but also to twist fibre to give it strength and durability: thus it can involve bringing together lines of becoming in constant movement and counter-movement – as in piled yarn and a good story (Klenk, 2018). As Harraway (2016 in Klenk, 2018) claims, each time a story helps me remember what I thought I knew, or introduces me to new knowledge, a muscle critical for caring about flourishing gets some aerobic exercise. Such exercise enhances collective thinking and movement in complexity.

The following image captures the idea of knotting, twisting, yarning and telling a story.

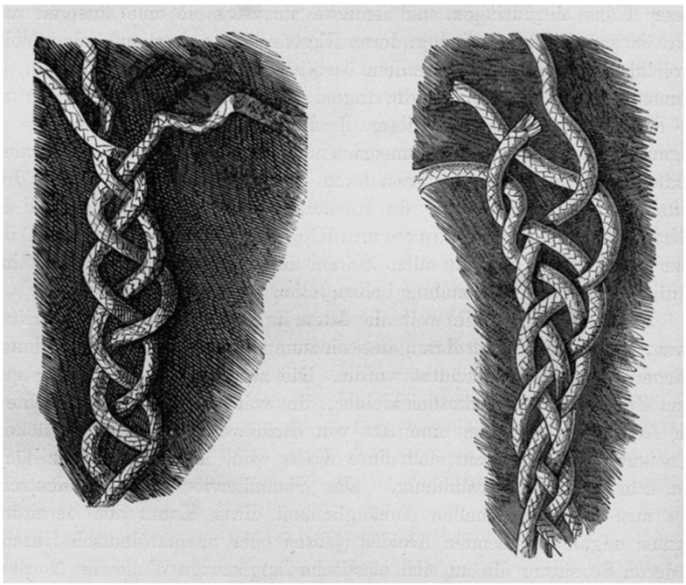


Figure 10: Knotting [Ingold, 2005]

Those using the social network tool consider network measures can include 'density' (the number of all possible connections among individuals) and 'centralization' (the extent to which a network

is dominated by a single or a few highly connected individuals, hence reflecting a hierarchical distribution of power).

When knowledge and individuals are framed as 'dots' that are connected through collaborative research, it is not possible to account for all the friction, disruption and uncertainty

On the other hand, the idea of meshwork is more helpful as it invites contrasts to unfold, and encourages us to refrain from our habitual tendency to diagnose, survey, and construe difference into familiar objects and relations – it has the potential to disrupt our tidy methodology and objectives (Klenk, 2018). A meshwork approach encourages us to become skilled at being with others and witnessing their personal experiences. This requires us to pay attention to moments of interruptions, awkward speeches or silences, and unanticipated stories unfolding.[22]

4.6.2 Meshwork and yarning

The idea of yarning is to from the verb 'to yarn' which is to tell a story. It is also about twisting and turning fibre so that it moves from being one thing to having a new form. As one twists one gives new durability – and implies constant movement and counter-movement.

[22] See Goldin et al. (2021) for an understanding of the messiness, surprise and unexpected elements of citizen science. Here the image of the aquifer itself – with its meanderings and unexpected turns – mimics what is the reality on the social front, In the same way that groundwater itself is fluid – so too are emotions – shame, anger, disgust, pride, joy, disappointment – desires and aspirations as well as multiple differing claims and demands on water that together form a messy reality

Figure 11: Yarning or Telling a story

Meshwork and yarning also explains well the entanglement of individuals – full of loose ends and always on the move. And as Klenk and Meehan (2017) remind us, when knowledge and individuals are framed as 'dots' that are connected through collaborative research, it is not possible to account for the friction, disruption and uncertainty manifest within the real world. According to Ingold (2015), in a world of life – it is knotting that is the fundamental principle of coherence. It is the forms are held together and kept in place within what would otherwise be formless. Knotting is about contrary forces of tension and friction as in pulling tight – and the way these generate new forms. When we think of the complex institutional, social, political and environmental landscape that we have presented above, it is helpful to keep in mind images of knotting, yarning and entanglement.

And given the historical timeframe within which our current study is underpinned, it is fitting to end this section of the report by presenting the corona image as corona brought with it disruption from the outside, adding more loose ends, distortions and tensions – once again part of the 'social' – association we have discussed above.

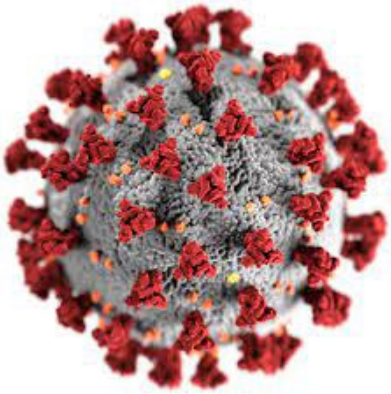


Figure 12: Image of Corona Virus

Part Five: Proposition for a POPLUC model

5.1 Model hypothesis

As a scaffold for POPLUC we develop a model that can be applied within the Hout and beyond. The hypothesis for the model is as follows: a nexus approach allows for wiser and better management of water resources in the catchment and provides the pivot for ideas of polycentricity, pluralism and CS. The application of the POPLUC model encourages us to interrogate the multiple centres of governance, authorities, stakeholder entities and the multiplicity of power, equality or privilege (or lack thereof) that influence the way decisions are taken. We present two models, both of which capture the notion of polycentricity, pluralism and citizen science. The first model is a flow chart with the central ideas of meshwork and knotting holding the model together – the icon above each box is the meshwork symbol. There is movement between the concepts (boxes), with flow around notions of power and privilege, influence and decision-making. In the first box we capture the idea of governance where we have put ward councillors, local government, Department of Water and Sanitation, agricultural union, education institutions and so forth. These entities are entangled and are also influenced by power and privilege. Citizen science captures key ideas concerning knowledge generation, scientific (water) literacy, participatory processes, social well-being, meshing and knotting with ideas of pluralism such as rights, complexity, empowerment, subjectivity, social diversity, values and so forth. The third category here – also connected through the idea of meshwork and knotting and influencing decision-making, is pluralism highlighting empowerment, subjectivity, difference, complexity and so forth.

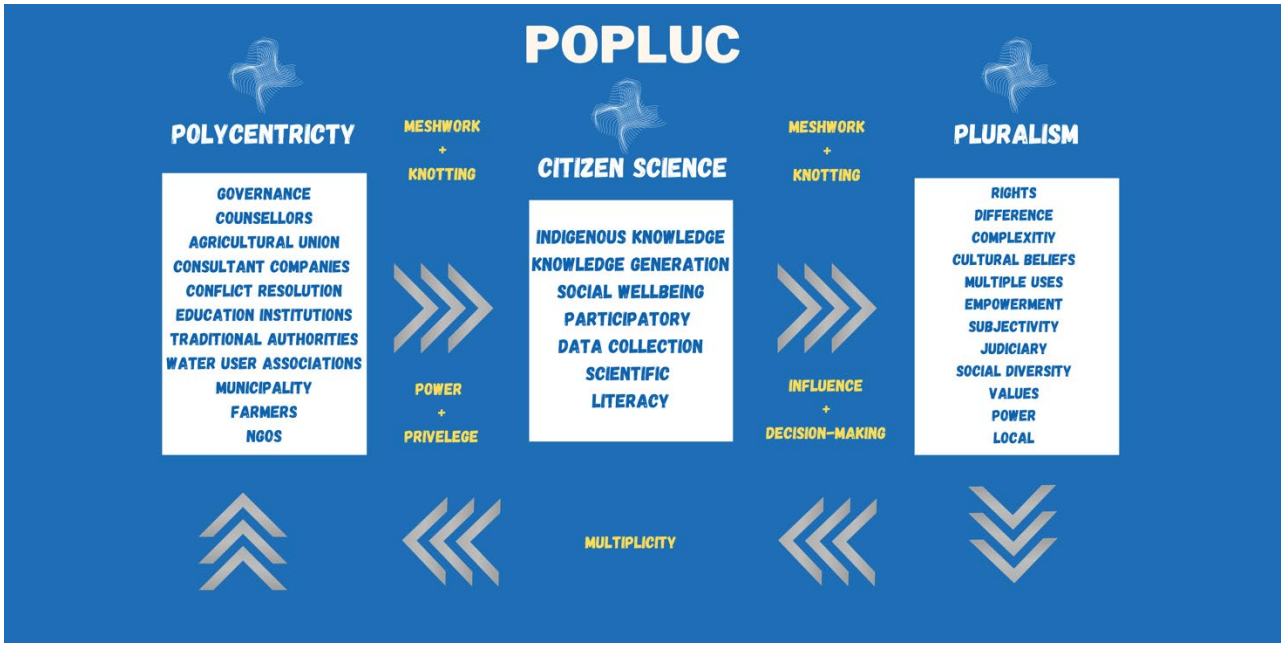


Figure 13: POPLUC model version one

In our second model (see below) we move away from the flow chart and the 'box' interaction between the three concepts to represent the idea of a nexus where the concepts of polycentricity, pluralism and citizen science intertwine and circle within each other. This version complements the first version of the model. Our second version reflects connectivity between nominated concepts through concentric circles. The nexus idea holds the concentric circles together. Here we also present the idea of overlapping jurisdictions, with the circle of polycentricity mimicking multiple stakeholder influences and institutional diversity through a nexus lens. The vocabulary of polycentricity, pluralism and citizen science is echoed in the circles as in the first version of the model above.

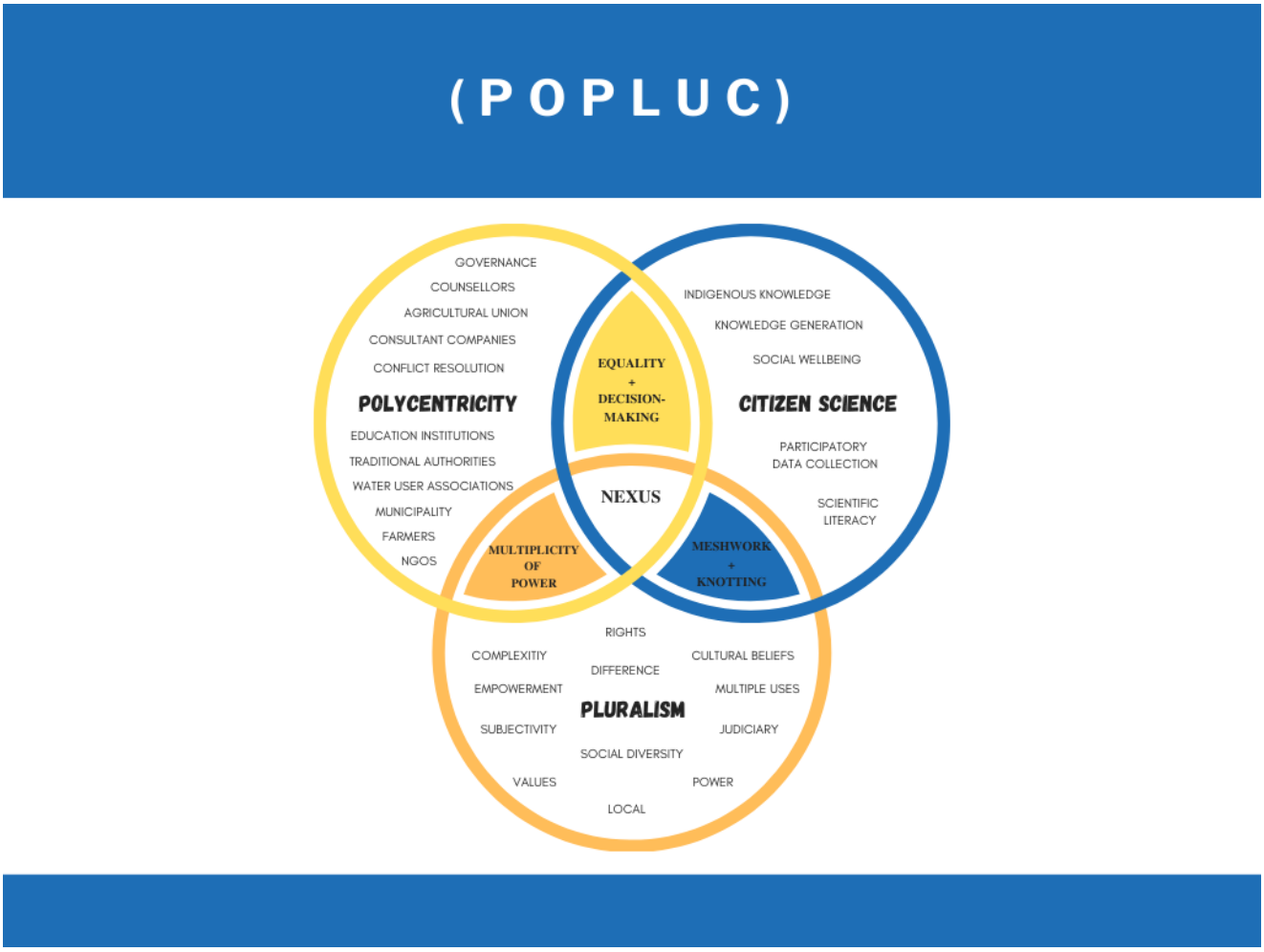


Figure 14: POPLUC model version two

The many aspects of CS, such as scientific (water) literacy, social well-being, democratisation of knowledge and so forth are tightly linked to the ideas of pluralism with multiple sites of power, subjectivity, cultural beliefs and values. The key notion of entanglement and meshwork is seen through the nexus lens as is the idea of balance where there is equality and decision-making, implying that no single stakeholder can stand alone and although diverse, there is no one stakeholder that is more equal than another. Power and privilege lie on the same axis as influence and decision-making, drawing attention to the relationship between power and privilege and that of influence under particular decision-making regimes. We believe that these two models are relevant when presenting the ideas behind POPLUC and in their application allow us to reflect on the key features contained in each of these concepts – separately – and the way they relate to one another – together.

However, in the spirit of this study and our responsiveness to images of yarning, entanglement and surprise we propose a more fluid model as we find both models too static. This third

representation is in the form of a storyboard. Although it is helpful to keep in mind the vocabulary of POPLUC that is 'cast in stone' in model one and model two above, the imagery captured on the storyboard below, is, we believe, more helpful. According to Wikstrom (2013 in Ayob and Omidire, 2021), the storyboard dates back to the 20th century when it served as a pre-visualisation tool for the film industry in a graphic storytelling and visual narrative form. Storyboarding is a technique used in the visual arts and has been adapted for use in indigenous research regarding community development (Simeon et al., 2010 in Ayob and Omidire, 2021) and in participatory research (Pittaway and Bartolomei, 2012 in Ayob and Omidire, 2021).

Figure 15: POPLUC model version three [story board]

We see the storyboard as another manifestation of yarning – as in telling a story. As stated above, meshwork – and yarning – explains the entanglement of individuals, full of loose ends and always on the move (Klenk, 2018). Or as Ingold (2015) claims, in a world of life – it is knotting that is the fundamental principle of coherence and that is generative of new forms. The storyboard yarns loose ends and new forms. There is certainly a visual or visceral aspect to science that is not easily portrayed in academic writing and the storyboard gets closer to seizing this.

In our discussion on meshwork, we have argued that unlike actor network mapping, meshwork captures more realistically the entanglement and complex arena of citizen science. As we take science into the public arena we emphasise tensions, disruptions, connections and disconnections. In so doing we move away from the impulse to erase doubt or error as we acknowledge and make visible the unknown, the confused and the contradictory aspects of polycentricity, pluralism and citizen science.

Part Six: Bibliometric and scientometric analysis summary

Finally, we turn our attention to bibliometric and scientometric analysis where we explore how citizen science, pluralism and polycentricity have, or have not, been taken up in the literature. The first section of this part will present a brief overview of the bibliometric analysis data while the scientometric analysis data will follow in the second section.

6.1 Bibliometric analysis

Bibliometric analysis is defined as a statistical evaluation of published scientific articles, books, or chapters of a book, and it is an effectual way to measure the influence of publication in the scientific community (Iftikhar et al., 2019). This bibliometric analysis aims to evaluate the article output of publications with the keywords citizen science, pluralism and polycentricity, with particular interest in determining how many times these keywords co-occur in publications.

Table three presents the bibliometric data of the search results obtained from Scopus database based on the three keywords. In the first row, the number of search results (total documents) obtained for each keyword is presented. This number consists of all the materials that have the specific keyword (these are; journal articles, conference papers, books, and book chapters). The number highlighted in red represents the number of journal articles that have got the respective keyword. The top 3 subject areas, countries, and authors of material that has the respective keyword are also presented as well as the year range (the years over which the respective data has accumulated). For each subject area, the percentage of the material found in each respective category is presented and the number of articles for each of the authors is also presented.

Table 3: Document search results from Scopus based on keywords: polycentricity, pluralism & citizen science

	Polycentricity	Pluralism	Citizen science
No. of search results	660 (537)	19 718 (12 851)	19 601 (12 483)
Year range	1975 - present	1893 - present	1897 -present
Top 3 subject area	Social Sciences – 43.4 % Environmental Science – 20.8 % Econ., Econometrics & Fin. 8 %	Social Sciences - 41.6 % Arts & Humanities - 28.2 Medicine - 5.9 %	Social Sciences - 24.7 % Environmental Science - 12.1 % Agric. & Bio. Sciences - 9.5 %
Top 3 countries	USA, China & UK	USA, UK & Canada	USA, UK & Germany
Top 3 authors	Derudder, B.(16): Sun, B. (13) Li, Y. (11)	Bavinck, M. (22); Ruquerjo, F (20) Crowder, G. (19)	Fin, D. (41); Callaghan, C.T. (37); Crowston, K. (35)

The data presented in table three shows that there were 660 search results on polycentricity of which 537 are journal articles starting from the year 1975 to the present. Furthermore, we see that 43% of these articles are in the social sciences whilst 21% are in environmental sciences. We move then to pluralism and here there are 19 718 documents of which 12 851 are journal articles. The first of these goes right back to 1893 and here we see more in the social sciences (41.6%) and arts and humanities (28.2%). Interestingly, citizen science is first mentioned in 1897. Here there are 19 601 documents mentioning citizen science of which 12 483 are journal articles.

The data presented in table four, was collected in the same way as the data in table three, apart from the fact that the data in table four was generated by pairing the individual keywords and creating a data set. So, each data set was formed by searching for materials that have the two keywords appearing together in the same document. The results generated show that there are documents in which two of these keywords appeared alongside each other.

Table 4: Document search from Scopus based on coupling of the keywords polycentricity, pluralism & citizen science

	Pluralism & polycentricity	Pluralism & Citizen science	Citizen science & Polycentricity
No. of search results	63 (33)	1 464 (946)	8 (4)
Year range	1997 - present	1972 - present	2010 -present
Top 3 subject area	Social Sciences - 57.6 % Arts & Humanities - 16.3 % Econ., Econometrics & Fin. 7.6 %	Social Sciences - 54.6 % Arts & Humanities - 18.7 % Environmental Science -5.1 %	Social Sciences - 41.7 % Econ., Econometrics & Fin. 2 % Agricultural & Bio. Sciences -1 %
Top 3 countries	UK (14); Canada (10) & USA (10)	USA (444); UK (194) & Canada (110)	USA (7); Canada (1) & Germany (1)
Top 3 authors	Tuori, K. (4): van Meeteren, M. (4) & Belley, V.G. (3)	Brown, J. (6); Fives, A. (6) & Dillard, J. (5)	Durant, R.F. (2); Ali, S.B. (1) Basurto, X. (1)

The data presented in table three couples the concepts. The highest appearances were on pluralism and citizen science. This would be expected considering the fact that research in these areas started in the 1890s, whilst research on polycentricity started as late as 1975 and is still growing and gaining interest. Here we see pluralism and polycentricity give only 63 documents of which 33 are journal articles. The first time the two keywords appeared together is in 1997.

Most (58%) are in the social sciences, 16% in the arts and humanities and 8% in economics, finance, and econometrics (these percentages are based on the total documents, i.e. conference papers, journal articles books, and book chapters). Of these 14 are published in the UK, 10 in Canada, and 10 in the USA. There were no documents found that were published by South African authors/institutions. Moving onto the keywords pluralism and citizen science we find many more occurrences as there are 1 464 documents of which 946 are journal articles. There is also an increasing interest in the two keywords (coupled together). The first time these concepts were linked was in 1972 and here again, they are mainly found in journals on social science (55%) or arts and humanities (19%). A few are in the environmental sciences. The vast majority (444) are from the USA, 194 are published in the UK, and 110 in Canada. There was a total of 24 documents that were published by South African authors/institutions. When we look at the words citizen science and polycentricity there are far less publications with 8 documents in total – only 4 of these are journal articles dating more recently from 2010 to the present. In this list, no document was published by either South African authors or institutions.

Where we see our work makes a significant contribution to science is in the coupling of the three keywords. Table five presents the search results based on all three keywords.

Table 5: Bibliometric summary of data generated based on three keywords: Polycentricity, pluralism & citizen science

	Pluralism, Citizen science & polycentricity
No. of search results	7 (1)
Year range	2000 – present
Top 3 subject area	Social Sciences – 75% Arts & Humanities – 25%
Top 3 countries	Canada (3); UK (3) & Germany (1)
Top 3 authors	Bhamra, M.K. (2); Barber, N. (1) & Menski, W. (1) .

Here there are only 7 documents in total, of which only one is a journal article. The publications start in 2000 and are almost all in the social sciences. None are in the environmental sciences. Our study is thus unique in combining these three concepts in a study on water resources management. The following is a list of the 7 documents generated as search results using the 3 keywords:

Barber N (2011). The Constitutional State. In The Constitutional State, 1-224

Bhamra MK (2011). The challenges of justice in diverse societies: Constitutionalism and pluralism. In The Challenges of Justice in Diverse Societies: Constitutionalism and Pluralism, 1-253

Bhamra MK (2016). The challenges of justice in diverse societies: Constitutionalism and pluralism. In The Challenges of Justice in Diverse Societies: Constitutionalism and Pluralism 1-253

Menski W (2006). Comparative law in a global context: The legal systems of Asia and Africa, second edition. In Comparative Law in a Global Context: The Legal Systems of Asia and Africa, Second Edition 1-674

Solanki G (2011). Adjudication in religious family laws: Cultural accommodation, legal pluralism, and gender equality in India. In Adjudication in Religious Family Laws: Cultural Accommodation, Legal Pluralism, and Gender Equality in India 1-403

Von Benda-Beckmann K and Turner B (2020.) Anthropological roots of global legal pluralism. In The Oxford Handbook of Global Legal Pluralism 67-141

Wilson, R.A. (2000) Reconciliation and revenge in post-apartheid South Africa: Rethinking legal pluralism and human rights. In Current Anthropology 41(1) 75-98

6.1.1 Publication by year

The number of publications per year for each pair of data set is presented in the following figures. Image twelve presents the evolution of research based on pluralism and polycentricity.

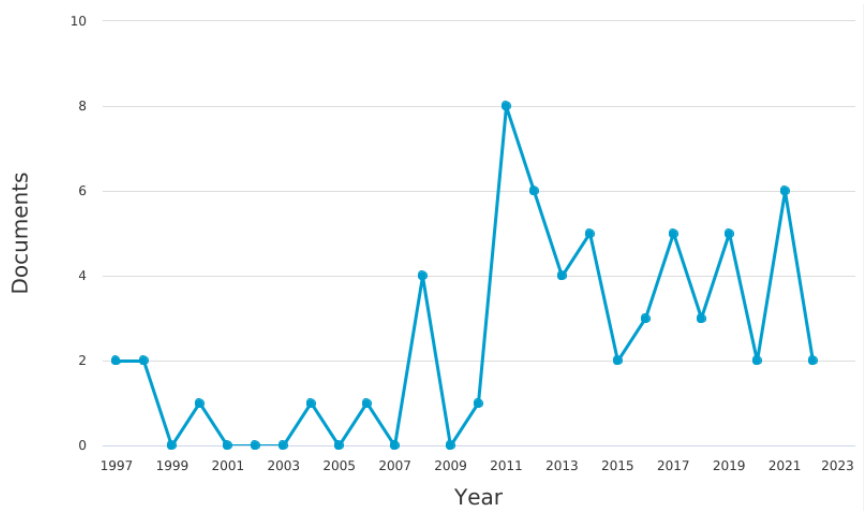


Figure 16: Number of documents per year for research based on pluralism & polycentricity

For the research on pluralism and polycentricity, there is a peak around 2011-2013 and this drops again after this date. The graph one indicates the number of documents produced per

year that have the keywords pluralism and polycentricity. It can be seen that the field has generally been gaining interest with an upwards trend from its inception in 1997. There has been a noticeable growth although the document output has remained relatively low, with the highest number of research documents per year produced (8) in the year 2011. Graph two below presents the document output per year based on the keywords pluralism and citizen science.

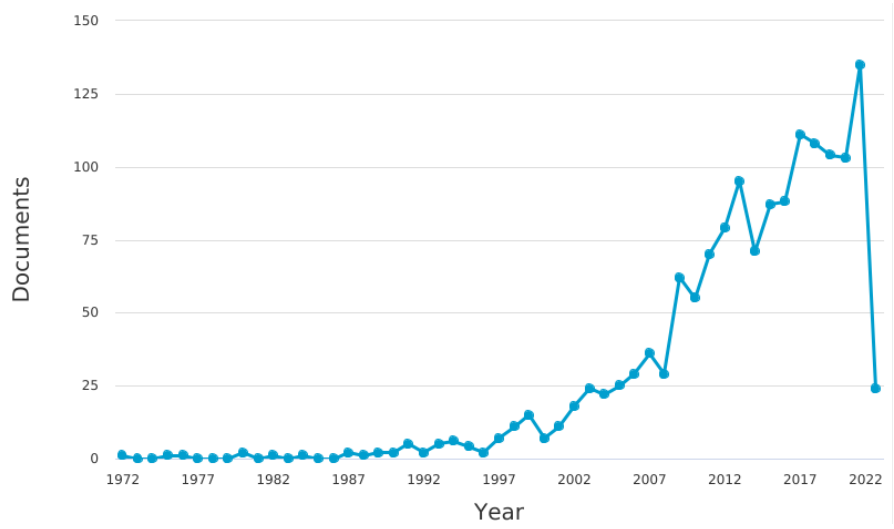


Figure 17: Number of documents per year for research based on pluralism & citizen science

The data in graph two shows that there has been a marked increase in research based on pluralism and citizen science. Active research started around 1972 but remained minimal up until around the year 2000 where it started to grow rapidly. Graph three presents the document output evolution on research based on citizen science and polycentricity.

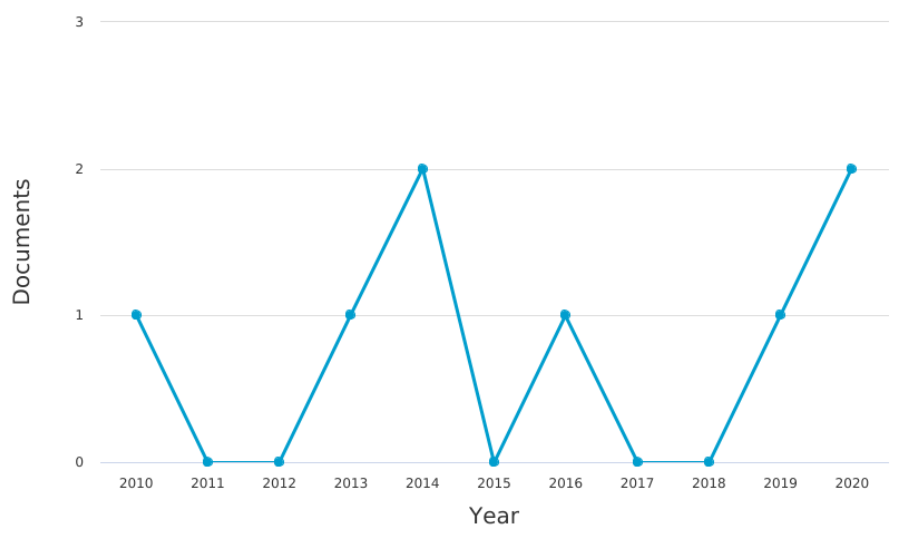


Figure 18: Number of documents per year for research based on citizen science & polycentricity

The data presented in graph three shows that there has been active research on citizen science and polycentricity since around 2010. The number of documents published per year has been haphazard, but the mere fact that there is active research in the field confirms the burgeoning interest in the field.

6.2 Scientometric analysis

Scientometrics is the study of the quantitative aspects of the process of science as a communication system. It is centrally, but not only, concerned with the analysis of citations in the academic literature. In recent years it has come to play a major role in the measurement and evaluation of research performance (Mingers and Leydesdorff, 2015). The scientometric analysis of the data generated by each pair of keywords was done by considering co-authorship (authors and countries), co-occurrence of keywords, and document citations. However, in this section, only the co-occurrence data is presented. The co-occurrence is based on the keywords and is defined as "a collective interconnection of terms based on their paired presence within a specified unit of text." It should be noted that there are two types of keywords, the author keywords and the indexed keywords. The author keywords are chosen by the author to best reflect the content of the document while the indexed keywords are chosen by the database (in this case Scopus) and are standardised to vocabularies derived from thesauri that the database owns or licences. Unlike author keywords, indexed keywords take into account synonyms, various spellings, and plurals. For our analysis "all keywords" were used, these are a combination of both the author keywords and the indexed keywords.

A keyword co-occurrence analysis was carried out using VosViewer software. The co-occurring keywords reflect research hotspots within a field (Xiao et al., 2017). Image fifteen presents the

keyword co-occurrence cluster view based on search results generated using the search words pluralism and polycentricity. The total number of keywords obtained was 232 and those with a minimum occurrence of 2 were selected leaving a set of 20 keywords which were then used to create the cluster in image fourteen. All the searches for keywords analysis were based on "all keywords" which includes both author keywords as well as indexed keywords.

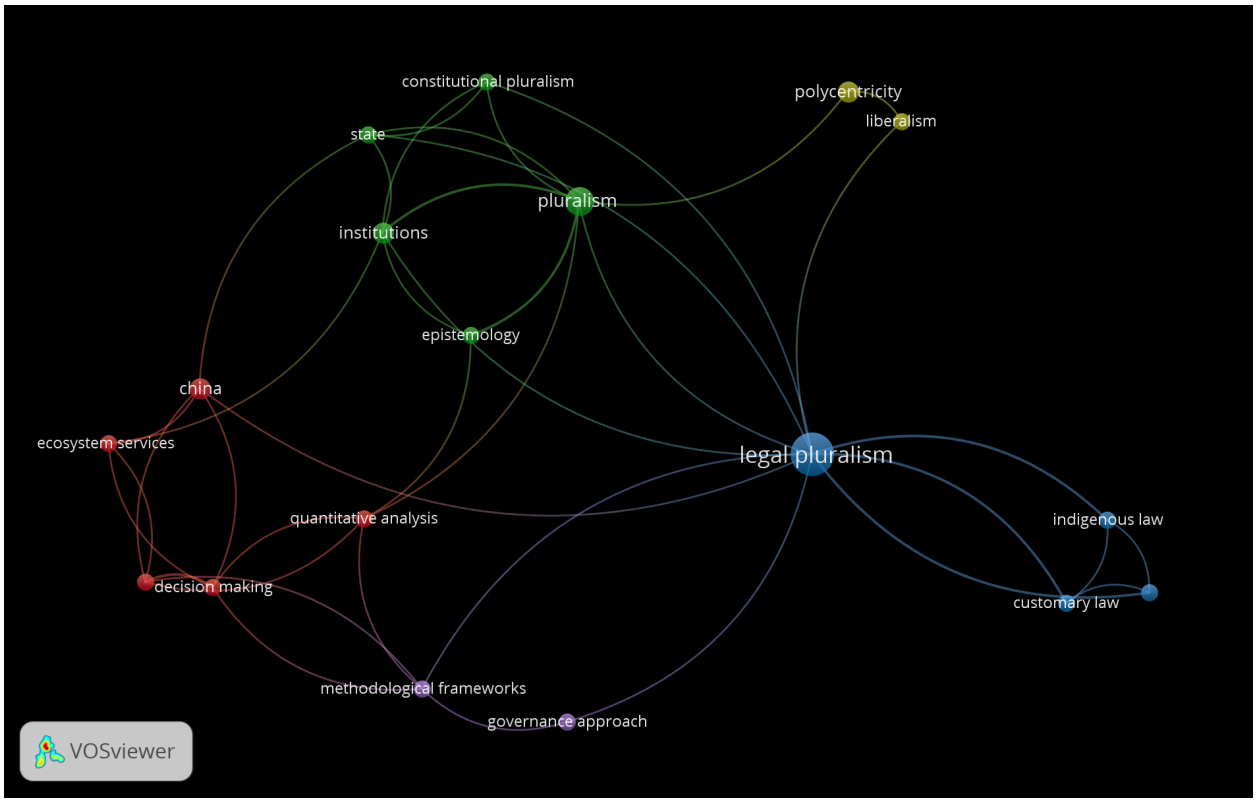


Figure 19: Co-occurrences [all keywords] network based on pluralism and polycentricity

In image fourteen both the node area and font size correspond to the weight value of the keyword. The larger the number of occurrences of a keyword, the larger the node and font. A line linking the keyword indicates that it appears in common with the other keyword(s), while the thickness of the line is indicative of the strength between the keywords. Thus, the thicker the connecting line, the more times the keywords appear together. From the cluster in image fourteen it can be seen that there is a reasonably high co-occurrence strength between the keywords pluralism and polycentricity. In the image, we see the context within which pluralism and polycentricity link with other keywords. Legal pluralism is the keyword that appears most often with legal pluralism being linked to polycentricity.

The software was also used to create a co-occurrence cluster chronology of keywords. This depicts the first occurrence time between a set of keywords and helps understand the research

field's hot spots and developmental evolution. The colour of the line linking the keywords is indicative of the first occurrence time of the two keywords while the line thickness indicates the co-occurrence intensity. Image fifteen presents the co-occurrence chronology view based on the search results on pluralism and polycentricity.

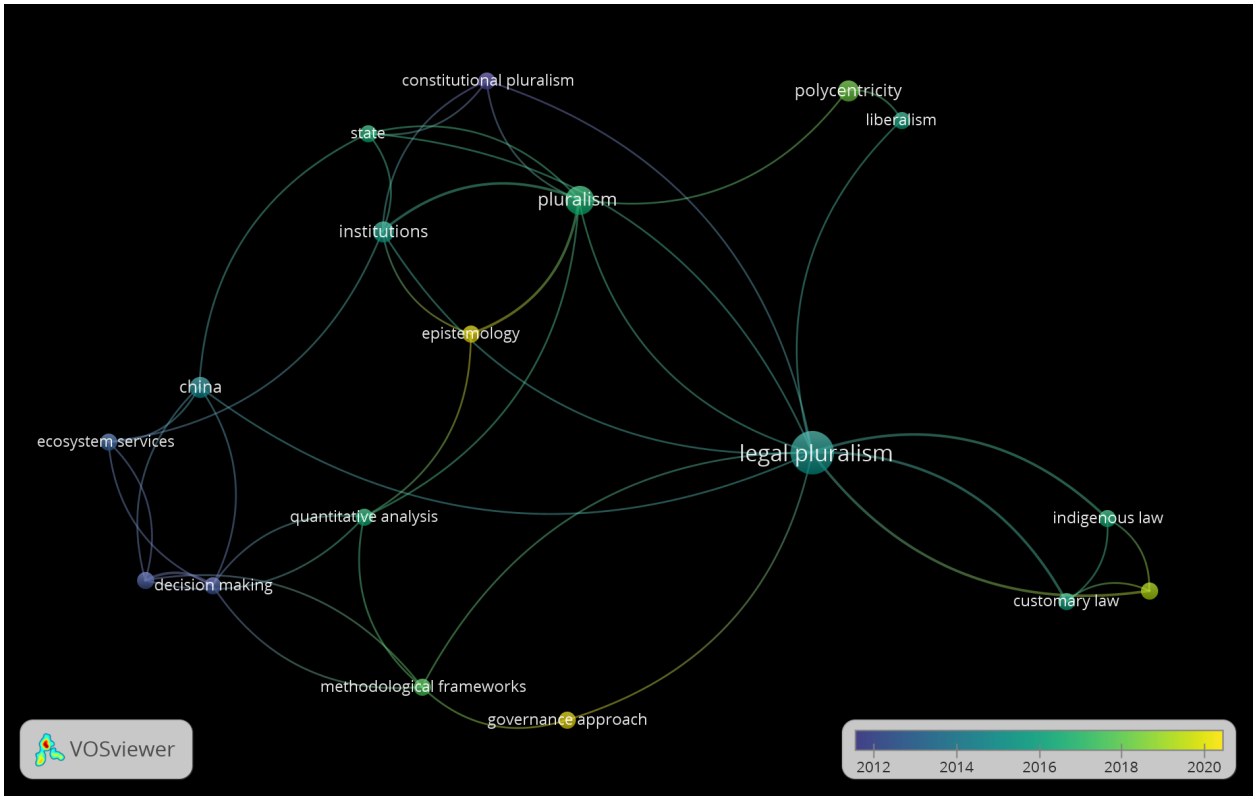


Figure 20: Co-occurrence chronology view of keywords: Pluralism & polycentricity

The image shows that the keywords pluralism and polycentricity started having significant co-occurrence strength around the year 2018. However, the data presented in table four shows that the two keywords started appearing together in 1997 but the co-occurrence was relatively low and insignificant. In 2020 the words governance approach and epistemology appear for the first time. Image thirteen shows the co-occurrence of all keywords that appear with pluralism and citizen science. In the search, the total number of keywords obtained was 4643 and those with a minimum occurrence of 5 were selected leaving a set of 244 keywords which were then used to create the cluster in image thirteen.

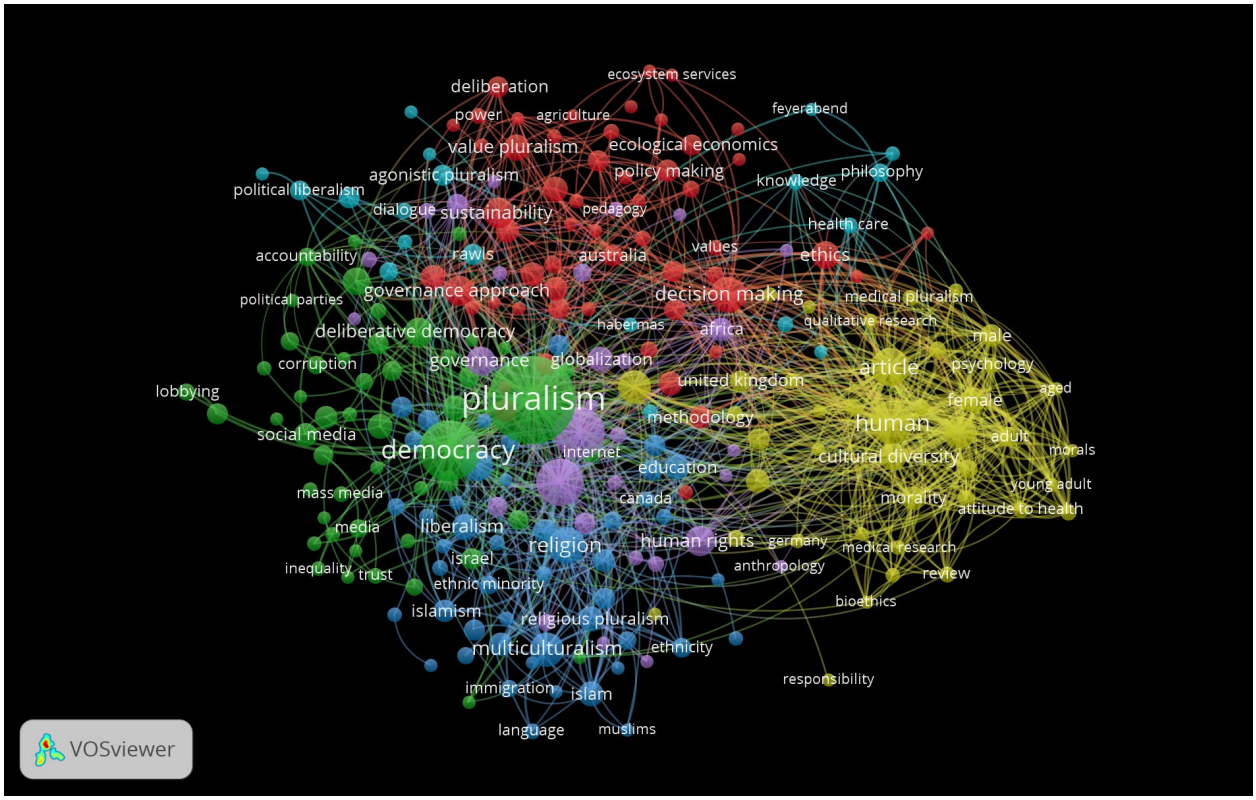


Figure 21: VOSviewer keywords co-occurrences clustering view [pluralism & citizen science]

The keywords co-occurrence cluster view presented in image sixteen shows that the keyword pluralism has high co-occurrence strength with other keywords such as citizenship, democracy, multiculturalism, legal pluralism religion and humans. From the image, there is no visible link between pluralism and citizen science and yet the data tabulated in image thirteen indicates that the two keywords appeared together for the first time in 1972. This simply means that the link between the two keywords could not fit into the selection criteria used to create the cluster. However, links between pluralism with other keywords such as local participation, participatory approach, education and participation are linked to pluralism in varying co-occurrence strengths.

The third group of keyword analysis was based on citizen science and polycentricity. From the data presented in table four, it can be seen that only 8 search results were obtained when searching the database (Scopus) using the two keywords. There was no link found between these two keywords despite the fact that a set of documents were found as search results. The main reason for this was the fact that most of the document search results were books or book chapters which are usually written without keywords. This is confirmed by Mingers and Leydesdorff (2015) who note that there are limitations in scientometric analysis of documents in the humanities and social sciences since most of the findings in these study areas are published in books rather than journal articles. This limitation affects co-occurrence analysis; however, the document sets

are not affected much since they are created via a term identification algorithm that searches for these terms in the titles and abstracts of documents.

Of the 8 search results obtained only 3 had a list of keywords. The first article by Boettke (2010) had the following keywords; collective action, governing the commons, political economy, and self-regulation. Apparently from that set of keywords, it would not be possible to create a link between citizen science and polycentricity even though the article addresses issues to do with both citizen science and polycentricity. The second article by Friesen and Mudigonda (2020) had the following keywords; agent-based model, collective behaviour, computational social science, cooperation, economic inequality, emergence, Hamilton, institutional formation, and urban. The third article by Quintana et al. (2020) had the following keywords; citizen science, conservation, environmentality, local ecological knowledge and Mexico.

In the keywords (co-occurrence analysis) for the documents search results based on the 3 keywords pluralism, citizen science, and polycentricity, 7 search results were generated and only 1 was a journal article with the rest being book chapters. Again, creating a rational keywords co-occurrence cluster was challenging due to the reason previously mentioned. The list of these documents was presented in section 6.1 above and the two documents with keywords are in Barber (2011); constitutional pluralism, institutions, legal pluralism, pluralism, social group, state and in von Benda-Beckmann and Turner (2020) – technology; anthropology of law; customary law; indigenous law; inter-legality; law and religion; legal complexity; legal pluralism; materiality; nomosphere; postcolonialism; transnationalization. Furthermore, it is important to note that of the 7 documents generated as search results using the 3 keywords, none of them were authored in Africa, they were authored in Germany, the United Kingdom and Canada.

Despite the cited limitation, an assessment of the keywords shows a noticeable absence of keywords around water resources management or groundwater. From our preliminary scientometric analysis, it is clear that the three words, polycentricity, pluralism and citizen science do not appear together as keywords. Our study therefore makes a contribution to the body of knowledge on each of these concepts. It also brings together water resources management in general and groundwater in particular. We find that our work provides a helpful direction and not only brings together for the first time these three concepts but brings them together for the first time in the context of water resources management, more particularly, groundwater monitoring.

Part Seven: Conclusion

In conclusion, the geographical terrain is a difficult terrain. The image below is pertinent.

Image fifteen: difficult terrain (source: DWS)

So too is the socio-political and environmental context, very much mimicking the images above – showing fragility, mobility, distortions and entanglement. Rittel and Webber (1973) introduced the term wicked problems. Such problems are linked, in complex ways, to many other related problems as well as to different interests or goals of a variety of stakeholders. Wicked problems are hard to define without at the same time considering possible directions to resolve them. A ready-made solution is not available. They can only be properly addressed when there is an understanding of the complexities of their broader context. Resolution of wicked problems can be approached step-by-step in trial-and error and it is impossible to define exactly when this resolution is 'good enough.'

Because of complexity – single interventions are not enough. We believe that one way to address – and perhaps sometimes to solve – 'wicked' problems is to look freshly at how we frame our questions. As such we have proposed the creation of a canvas where ideas of entangling, yarning and enmeshing can breathe. It is often tempting – and more so in this world of water (dominated largely by engineers, hydrologists, geologists, etc.) – to look to solutions

that can be 'quickly' grasped and implemented. We advocate for slow science and for a collaborative way of thinking where we accept that there can be doubt and more puzzling, albeit confusing, socio-political-environmental landscapes. We propose more fluid systems that form part of an enmeshment with material (and less material) assemblages and entanglements, thus offering a constructive step in the right direction towards accepting uncertainty and living with reasonable doubt. We allow for technical and social relations to collide and in so doing to take on new forms. Latour's image we presented where he referred to a lecturer and his material environment (the theatre designed by an architect, the podium used for the lecture, etc.) is pertinent and helpful in seeing how material aspects intertwine with social aspects. A citizen scientist measuring water in a borehole is affected by the borehole itself and instruments used to obtain the measurement. When data is sent through the citizen science app and captured on the website, it is being accessed by a member of the DWS, who, in turn, is affected by the institutional and legal realities of his/her working environment.

We advocate for slow science – accepting doubt and more puzzling, confusing landscapes that form part of an enmeshment with material (and less material) assemblages and entanglements

The evolution from a hydrometeorological monitoring landscape dominated by national networks to a more diverse community of multilevel and multipurpose monitoring bears strong resemblance to the emerging academic insight that water management, particularly in certain contexts, may benefit from a polycentric governance model. One tends to think of community science efforts as being isolated – but this is not so as these grassroots efforts are now becoming networked to tackle widespread issues of social and environmental justice as well as questions about effective conservation practice. Importantly, we were able to assert that there is no reason to believe that data collected by the volunteers is any less reliable than data collected by 'scientists.'

As a research team we too are entangled – we are governed by the rules of our own institute, the University of the Western Cape yet when we engage with a citizen scientist our rules are different. We meet the citizen scientist not in an office but in the field, in a terrain where rules and regulations are set by the citizen scientist and not by ourselves. We recognize silent (for

instance tribal authority) voices who claim influencing our timeframes and protocols. For example, we are unable to proceed with training until the tribal authority has been notified. And because of the geographical and social terrain (as presented vividly in image fifteen above), we are not always able to meet at the appointed time – requiring flexibility, mobility and agility to adjust and adapt.

We are aware of the divergence between what is intended and what actually unfolds. For instance, a large number of water laws protect customary water rights and yet these same laws do not provide the necessary details to clarify that interface between customary and statutory rights – thereby creating legal uncertainty to their de facto status and protection. The National Water Act does not formally acknowledge customary law and yet, when working in the Hout the power of the Chief was very apparent. It is likely that customary rules and rituals affect citizen scientists differently from how they affect (or perhaps don't affect at all) a government official sitting in his/her office in Polokwane. Traditional management systems are effective for water management because they are localized as opposed to conventional systems which require many more resources to penetrate to the local level. In practical terms, villagers are acquainted with indigenous knowledge systems and customary laws found within traditional governance systems where customary rituals and rites have far more significance. We find polycentricity a necessary but not sufficient concept to approach groundwater monitoring activities by citizen scientists. It is more realistic to take on the three key concepts together, polycentricity, pluralism and CS, what we have called POPLUC. Together these ideas capture the 'messiness' (but authenticity) of multiple centres of decision-making and an appreciation that society (citizen volunteers) should be considered as key players in addressing the hydrological void in data around groundwater. At the forecourt of our thinking is also an ethics of care which is always attentive to difference and diversity.

Because socio-ecological systems are characterised by multiple decision-making centres at multiple scales they require co-generation of knowledge as opposed to top-down single or monocentric approaches. This holds the potential for the democratisation of knowledge – and with it the emancipatory potential for improved stewardship of the resource. We see evidence of this in our work in the Hout which demonstrates how water resources monitoring operates at the grassroots. Through monitoring activities (and the WhatsApp group 'connector') citizens upstream in the catchment which is 2 480 km^2, having been isolated and distant in villages which are far apart, are now 'yarned' together, enmeshed with those living downstream. This resonates with Latour's powerful far/close analogy in section 4.5.6 above of someone being closer to their

mother who might be 6000 miles away than to the person in the telephone booth adjacent to them. The idea of far/close is also helpful when considering the less tangible goods (feelings and emotions). Someone measuring groundwater in one part of the Hout might have very similar experiences of pride, dignity and overall well-being to a citizen scientist monitoring water quality in a river in KwaZulu Natal using MiniSASS (see reference footnote 12). A government official in the regional Polokwane office who has a common vision of groundwater monitoring is now entangled with citizen scientists who are filling a hydrological void in a remote village in the Hout. Similarly, where apartheid built walls between commercial (white) and small scale (black) farmers – and where ghosts still linger – there are new pathways, or what Ingold calls 'taskscapes,' weaving or 'yarning' people closer to one another through the similarity of their tasks. 'Taskscapes' override cultural or historical divides. Our concerns about polycentricity, pluralism and CS around water are even more critical in the case of groundwater, which – as an invisible asset – runs under the ground with little knowledge about how much there is, where it is, how clean it is, what rules and laws govern its use, who makes these rules and finally how to extract, conserve and manage it. DWS simply cannot monitor wells that are in remote rural settings – or at least not to the extent that ordinary citizens are able to do – and this means new laws and rules and fresh ways of seeing apply in a particular context such as the one where our project operates. We have shown how yarning, knotting and entanglement help accept difference and diversity and provide a more realistic lens through which to consider polycentricity, pluralism and citizen science. The ideas of polycentricity, pluralism and CS are not abstract theoretical notions but are applicable to very real lived experiences.

Yarning, knotting and entanglement are concepts that help accept difference and diversity and provide a more realistic lens through which to consider polycentricity, pluralism and citizen science

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