KOEDOE - African Protected Area Conservation and Science
ISSN: (Online) 2071-0771, (Print) 0075-6458

Integrating multi-scaled and multidisciplinary studies: A critical reflection on the Kruger National Park research supersites

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Dates:
Received: 12 Sept. 2019
Accepted: 08 Jan. 2020
Published: 29 Oct. 2020

How to cite this article:
Smit, I.P.J., 2020, 'Integrating multi-scaled and multidisciplinary studies: A critical reflection on the Kruger National Park research supersites', *Koedoe* 62(2), a1586. https://doi.org/10.4102/koedoe.v62i2.1586

The Kruger National Park (KNP) research supersites were designed to encourage place-based research in order to geographically focus research activities on known and well described study sites as opposed to *ad hoc* site selection practiced previously. This was done by (i) delineating sites using a clear rationale, (ii) providing basic meta-data for these sites, and (iii) actively encouraging scientists to conduct research on these sites and share data freely. The underlying concept was that geographically focused research would facilitate data and knowledge exchanges and lead to long-term, multi-scaled and cross-disciplinary studies at these data-rich sites, facilitating an integrated and collectively developed understanding that would be hard to achieve otherwise.

This essay acts as a short-term reflection on the KNP supersites and an introductory text for the special issue focusing on the outcomes from a multi-disciplinary study conducted on the southern granitic supersite. It starts off by briefly introducing the supersite concept, followed by a reflection on the achievements and challenges towards achieving the main objectives of the supersites. In addition, and as part of the "data-begets-data" philosophy underlying the supersites (i.e positive feedback of place-based data attracting further research and hence collection of further data), updated lists of references and available datasets are provided.

Conservation implications: This paper highlights the successes and challenges of geographically focusing research in the KNP to the research supersites in order to facilitate integrative and multi-scaled learning in savanna systems. It also provides updated lists of references and available datasets to further stimulate research at these sites.

Keywords: Long-term ecological research sites (LTERS); Monitoring; Multidisciplinary studies; Integrative studies; Research supersites.

Introduction

Over the years, the Kruger National Park (KNP) has established a reputation as an 'outdoor laboratory', and has registered more than 700 research projects between 2005 and 2016, and published 556 papers between 2003 and 2013, both by in-house scientists and external collaborators from around the world (Smit et al. 2017; Van Wilgen et al. 2016). As a result, the park has become one of the most studied savanna conservation areas in Africa (Smit et al. 2017). Many of these studies have focussed on specific experimental sites where underlying drivers are manipulated, for example, herbivore exclosures (e.g. Asner et al. 2009) or plots where fire regimes have been manipulated (e.g. Higgins et al. 2007). However, for many projects that aim to study or monitor patterns and processes emerging under non-manipulated conditions, sites were selected in a haphazard and uncoordinated manner and, as a consequence, because of underlying heterogeneity, it was often hard to integrate data sets and knowledge across these disparate sites. In an attempt to geographically focus research effort and allow data integration over time and across themes, the 'KNP research supersites' was conceptualised. It was envisaged that through establishing these areas, some geographic focussing of research would be achieved with these sites increasingly acting as data-rich, long-term sites for monitoring and research. In many respects, the KNP supersites have objectives similar to long-term ecological research sites (LTERS) (e.g. Gosz, Waide & Magnuson 2010; Mirtl et al. 2018). The four KNP research supersites that cover the rainfall gradient

Note: Additional supporting information may be found in the online version of this article. Online Appendix 1; Online Appendix 2; and Online Appendix 3.

Note: Special Issue: Connections between abiotic and biotic components of a granite catena ecosystem in Kruger National Park, sub-edited by Beanelri Janecke and Johan van Tol.

(lower rainfall northern KNP and higher rainfall southern KNP) and geological contrast (basalt in east and granite in west) were formally introduced to the scientific community by Smit et al. (2013) who described the rationale, selection criteria and location of the sites, and introduced existing data sets describing environmental variables for each of these sites. The supersites' conceptualisation and delineation process started earlier (around 2011).

Six years after formally introducing the supersites and coinciding with this Special Issue focussing on a multidisciplinary project on the southern granitic supersite (Stevenson-Hamilton supersite), it is an opportune time to reflect on the successes of the KNP research supersites, the shortcomings and possible ways to further increase the value of these sites going forward. It is hoped that this reflection will also be useful for other situations where long-term research sites are being established. This essay will also act as a valuable reference document by providing consolidated and updated lists of research outputs and data sets (Online Appendix 1 – Online Appendix 3).

Research outputs from Kruger National Park research supersites (up to August 2019)

Since establishment, four Honours, four Master's and two PhDs have been completed on the supersites (Online Appendix 1). In addition, 24 peer reviewed articles (11 as part of this Special Issue, excluding this essay); two scientific reports; one book chapter; and one peer-reviewed conference proceeding have been published based on work fully or mostly conducted on the supersites (Online Appendix 1). Considering the relatively short existence of the supersites, the research outputs compare favourably to the number of research outputs associated with the KNP's well-established experimental burn plots (EBPs) that have been in existence since the 1950s (by June 2020, there were 79 papers published on the EBPs - Tercia Strydom [South African National Parks] pers. comm., 19 June 2020). The Skukuza flux tower is another example of place-based research in the KNP, linked to specialised equipment, which has attracted research attention and has been used as a study site for a range of studies (e.g. Majozi et al. 2017). It is also expected that as the supersites become better known and more data were accumulated, research at these sites will be further stimulated. It is anticipated that this Special Issue, which reports on integrative learning happening at the southern granitic supersite across a range of disciplines, will also advance the profile and increase the understanding of these sites, and will act as a further catalyst for stimulating research interest. Online Appendix 2 provides a list of a diverse range of papers and dissertations/theses known to the author that cite the supersites or make a reference to the KNP supersites concept, reflecting also on the broader impact the KNP supersites had in recent years.

Effectiveness of Kruger National Park research supersites in achieving original objectives

The following sections highlight six of the original objectives of the KNP research supersites and reflect on the effectiveness of the sites in achieving these objectives.

Objective 1: Attracting and geographically focussing research to established and well-described study sites

Based on a subjective assessment, it seems as if the KNP research supersites have, at least partially, managed to become geographical focal areas for research within the KNP. This geographical focus of studies makes it easier to integrate data sets or infer conditions between studies. The initial Smit et al. (2013) paper, which introduced the supersites concept, delineated the sites and provided a backbone of metadata that has proven valuable as a reference document for studies conducted on the supersites ever since. Most of the studies that have been conducted on the supersites refer to and cite this paper, as it provides a finer-scale description of the supersites than most other study site references that are usually available only at the regional or park-wide scale.

A comment that was raised by critics during the initial phases of delineation of the supersites was that the 'ideal' location of the supersites would be highly dependent on the specific objectives of each study, and that it would be hard to select sites that would 'fit-all'. Although this was acknowledged, the idea was never to optimise the supersites for a specific application but rather to delineate sites based on 'generic' principles and to make them potentially useful for a wide range of studies. As such, the final sites were selected based on a delineation of nested first- to third-order catchments entirely embedded within a single geology, across the rainfall gradient (north and south of park) and contrasting the geological divide (basalt and granite) in order to represent the dominant abiotic drivers in a nested hierarchy. Secondly, these sites had to adhere to some logistical criteria as well (e.g. close to research accommodation, accessible by all-weather roads from multiple directions and outside wilderness zones in order to allow instrumentation). As such, it is encouraging to note that the final supersite locations have proven suitable for a suite of themes, including studies on different taxonomic groups (vegetation, microbes, aquatic invertebrates, small mammals, bats, birds, and large mammals), abiotic patterns and processes (geology, soils, topography and hydrology) and development and use of technology (remote sensing) (see focal themes in Online Appendix 1).

Objective 2: Promoting integrated understanding across multiple disciplines and scales

Although there was some cross reference and data sharing within and between hydrological and geological/soil studies, it was apparent that many studies did not integrate with other studies nor were they following a multidisciplinary approach. This is probably to be expected as studies considering very dissimilar taxa or processes and at very different scales would not have obvious and direct linkages or these linkages may not be fully appreciated. Also, science is often still

approached using traditional discipline and specialist focal areas, with cross-disciplinary studies still in the minority. The multidisciplinary project conducted by the University of the Free State, and on which this Special Issue focusses, is an example where some level of coordination and integration has happened during the initial project design phase, continued through coordinated and spatiotemporally aligned field campaigns, and ultimately resulted in integrative dissemination (this Special Issue). Furthermore, some papers in this Special Issue attempt to make explicit the links between how the abiotic patterns (soils, geology and topography) influence the abiotic processes (hydrology, soil chemistry), ultimately giving rise to the biotic communities responding to the resulting heterogeneity (vegetation, large mammals, aquatic invertebrates and microbes). This project involved eight principal researchers representing six different departments (Soil Sciences, Groundwater Studies, Plant Sciences, Wildlife Sciences, Environmental Sciences and Microbiology), doing collective fieldwork campaigns and sharing ideas and data across disciplinary boundaries. Janecke et al. (2020) (co-authored by all principle investigators from diverse disciplines) makes a concerted effort to not only summarise but to some degree also integrate between the different studies conducted as part of this project, providing a conceptual framework for biotic and abiotic interactions and feedbacks.

Objective 3: Promoting free sharing of data

The supersites concept aims to leverage the 'data-begets-data' principle, and for this to function optimally, free sharing and easy accessibility of data are critical. This has been partially successful with the supersites, with data and metadata being archived on a centrally managed South African National Parks data repository.[1] However, various challenges were also experienced in this regard. Some researchers were not allowed or prepared to share data because of a range of reasons (e.g. restrictions linked to funding bodies). In other cases, researchers failed to respond to requests to share data, and KNP project coordinators were not effective in following up to ensure all data were appropriately archived. Another challenge is that in some cases data got shared and centrally archived, but search terms were ineffective for the data to be associated with the supersites, reducing the likelihood of other researchers working on the supersites being aware of the existence of the data. Online Appendix 3 provides a list of data sets and key reports currently available for the supersites and also indicates for which supersites the respective data sets are available.

Objective 4: Comparing abiotic contrasts

It was initially hoped that studies would collect and compare data across all four supersites in order to better understand the role of rainfall gradients and disparate geologies. This has proven problematic from the start – most of the studies focus only on one of the two southern supersites. This Special Issue is a point in case, focussing only on one of the four supersites. This is *inter alia* because of the fact that the southern supersites are in close proximity to Skukuza (the main research hub of KNP and also the closest supersite to reach from most universities, with the northern supersites adding another day of travelling), and these sites have higher rainfall, deeper soils, more heterogeneity and higher levels of biodiversity. This is further compounded by the financial implications of repeating fieldwork at all supersites. With the exception of remote sensing studies and one geology study, all of the studies in Online Appendix 1 were conducted on the southern supersites. As such, the northern sites (which represent about half of the KNP abiotic template) have not received any notable research attention. It is anticipated that the knowledge and data disparities between the southern and northern supersites will continue to increase. Although not a problem *per se*, it is foreseen that this gap will increasingly widen and the value of the northern supersites may prove to be very limited. Research coordinators within KNP could play a role in promoting these sites if and where appropriate and where logistical constraints allow.

Objective 5: Understanding long-term ecological dynamics

Another objective of the supersites was that it would become important long-term monitoring sites, similar to LTERS. Too little time has passed after the initiation of the sites to really assess whether the sites are contributing towards this objective. However, colleagues from the Skukuza Science Leadership Initiative (SSLI) in partnership with Florida University, USA, are already exploring some short-term vegetation and biodiversity trends and dynamics on the southern basalt supersite (2013–2019) (unpublished presentations). Van Aardt et al. (2020) and Janecke et al. (2020) also provide insights into short-term drought dynamics. In addition, various remote sensing projects have also explored long-term woody cover patterns on the supersites (although the historical data sets were collected independently of the establishment of the supersites).

Objective 6: Training sites for remote sensing products

Although various remote sensing projects have been conducted on the supersites using a range of sensors (aerial Light Detection and Ranging [LiDAR], aerial photography and optical satellite sensors [i.e. Satellite Pour l'Observation de la Terre {SPOT} 6]), the supersites have not been used as training or validation sites for remote sensing products. This is likely because of relatively little vegetation-related fieldwork and at scales inappropriate for linking to the remote sensing products. It is anticipated that wall-to-wall aerial LiDAR coverage across the supersites would significantly increase the value of these sites as training sites for development of global remote sensing products for savannas (multiple such requests have been received). Unfortunately, it has not been possible to acquire such data sets yet, but potential opportunities are being explored.

Discussion, recommendations and conclusions

The KNP supersite concept has gained traction, with research on a range of topics conducted on these sites since their

1 See https://dataknp.sanparks.org/sanparks/ (using 'supersites' as the search keyword).

establishment. Many of the studies in Online Appendix 1 could have been conducted at a number of locations within the park, yet the conceptualisation and delineation of the supersites seemed to have been instrumental in geographically focussing research. In the absence of supersites, these studies would most likely have happened at various unrelated sites across the park. Furthermore, the conceptual appeal and the rationale behind the supersites may even have attracted research projects to the park that may otherwise not have happened. It is believed that some of the reasons for research projects focussing on the supersites may have been (1) the clear ecological rationale behind the site selection, (2) the logistical benefits of working at these sites (i.e. easy access to research camps and other research support services), (3) the availability of good basic metadata and descriptions of these sites and (4) other research projects also being conducted at these sites, allowing opportunities for data sharing and collaboration.

Going forward, a concerted effort should be made to ensure that data management is improved to ensure that all supersite data are systematically collated, archived and easily accessible. Even if data archiving infrastructure is in place, follow-up and coordination is important to ensure that datasets get collated and centrally archived in a database with appropriate search terms. It is proposed that this database be continually updated in order to (1) increase awareness of the available data sets, (2) attract further research to the sites, (3) facilitate data sharing and integration, and ultimately (4) increase understanding of the role of top-down and bottom-up processes in savanna ecosystems.

Some limited measuring equipment (e.g. soil moisture meters) and small-scale manipulations (herbivore exclosures) have been added in recent years at some of the sites, which may further increase the value and research uptake. Installation of further long-term equipment (e.g. weather stations) and wall-to-wall coverage of valuable datasets (e.g. high-resolution airborne LiDAR and derived products like Digital Terrain Model [DTM] and Digital Surface Model [DSM]) should be promoted, as it will act as additional catalysts for further studies on the supersites. In addition, the sites may gain further traction if they become more formally part of the research infrastructure networks and increase their involvement with international collaborators and LTER initiatives. Dedicated research budget, solicited research and well-funded projects on these sites can also contribute towards the objectives set out in this essay.

Where the KNP research supersites provide a good 'fit' for the purposes of studies, they should be actively promoted as potential field sites. As per their original conceptualisation, it is believed that the longer these sites are in existence and the more they are studied (and with associated data sets becoming freely available), the more valuable they will become and the more research attention they will attract, contributing towards answering questions that would not be possible with individual projects, which are typically funded only for three- to five-year cycles. This Special Issue, together with the earlier work of Riddell et al. (2014), and other studies listed in Online Appendix 1 are a testament to how the KNP supersites are contributing towards improved understanding of bottom-up and top-down drivers of and responders to savanna heterogeneity. It is hoped that over time, and as more studies are conducted on these sites, more integration would emerge between studies that can benefit from multidisciplinary approaches.

Acknowledgements

The author thanks Edward S. Riddell, Beanelri Janecke and Johan van Tol for comments on an earlier draft.

Competing interests

The author declares that he has no financial or personal relationships that may have inappropriately influenced him in writing this essay.

Author's contribution

I.P.J.S. is the sole author of this research article.

Ethical considerations

This research followed all ethical standards for research without direct contact with human or animal subjects.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

Data sharing is not applicable to this essay as no new data were created or analysed.

Disclaimer

The views and opinions expressed in this essay are those of the author and do not necessarily reflect the official policy or position of any affiliated agency of the author.

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