SHORT COMMUNICATION

INTRODUCING DIGITAL DATA COLLECTION FOR BIOSECURITY SURVEYS AT THE SOUTH AFRICAN SUGARCANE RESEARCH INSTITUTE (SASRI)

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Abstract

Pests and diseases pose a significant challenge to the South African sugar industry. To address these threats, 24 field inspection teams operate within the 12 Local Pest, Disease and Variety Control Committee (LPD&VCC) control areas across the industry. These teams, collectively known as the Biosecurity Inspectorate, are managed by the South African Sugarcane Research Institute (SASRI). The Inspectorate provides LPD&VCCs and individual growers with vital field data, which enables informed decision-making for the effective monitoring and management of biosecurity threats.

Until recently, a paper-based data collection system was used by the Inspectorate in the field for pest and disease surveys, and the data were manually captured in an electronic format by administrators in each LPD&VCC area. To improve the efficiency of the data capture and processing, electronic data capture systems using ArcGIS Survey123 were configured for mobile devices that can be used in the field. Initially, forms were developed for routine surveys for the stalk borer *Eldana saccharina*, and for disease surveys, where fields are inspected for smut (*Sporisorium scitamineum*), mosaic (sugarcane mosaic virus) and off-type varieties. The electronic data capture system offers many benefits, including increased efficiency and improved accuracy. Inspected fields are geo-referenced, and the captured data are stored in a geodatabase. The system is real-time and allows the visualisation of data using operational dashboards that are linked to the field data. In addition, each form includes a section for capturing valuable observational data for other pests and diseases. Applications for ratoon stunt (RSD, *Leifsonia xyli* subsp. *xyli*), certified and approved seedcane inspections, as well as fallow field inspections, are currently in development, which will ultimately be combined into a seedcane tracking application.

Keywords: ArcGIS Pro, biosecurity, dashboard, GIS, pest and disease, PostgreSQL, Survey 123

Introduction

The South African sugar industry operates across two provinces, KwaZulu-Natal and Mpumalanga, and it plays a pivotal role in the national agricultural economy by means of its contribution to employment, rural development and export earnings (Baiyegunhi, 2024). However, sugarcane production remains vulnerable to an array of pests and diseases that adversely affect the yield, quality, and long-term sustainability of sugarcane. In this context, biosecurity, defined as a strategic and integrated approach to the analysis and management of risks to agriculture, has become increasingly central to the resilience of the industry (Stranack, 2021).

Biosecurity management within the South African sugarcane industry is structured around a network of Local Pest, Disease and Variety Control Committees (LPD&VCCs), which the Biosecurity Inspectorate supports. The Inspectorate is responsible for conducting routine field inspections, it monitors the prevalence of pests and diseases and delivers timely information to direct local decision-making processes (Stranack, 2021). Historically, these activities depended on paper-based data collection systems, which were time-intensive and susceptible to transcription errors, data loss and inefficiencies in data management and reporting.

The Biosecurity Inspectorate focuses primarily on three key areas: Eldana inspections, disease inspections, as well as surveys for ratoon stunt (RSD; *Leifsonia xyli* subsp. *xyli*). This paper concentrates on the digital transformation of Eldana and disease inspection results. Eldana (*Eldana saccharina*), the indigenous stalk borer, represents the most significant pest threat to the industry, and it is responsible for yield losses that are estimated at approximately US$62 million annually (Zhou, 2022). Disease surveillance efforts centre on the detection of smut (*Sporisorium scitamineum*), mosaic (sugarcane mosaic virus) and the identification of off-type varieties. Smut is most prevalent in the coastal and irrigated regions, while mosaic predominates at higher altitudes (Zhou, 2022). According to McFarlane *et al*. (2018), losses attributable to smut and mosaic were estimated at R15 million per annum.

The digital transformation of biosecurity in the sugar industry, particularly through the integration of Geographic Information Systems (GIS) and mobile data collection technologies, offers significant opportunities to enhance surveillance systems. The adoption of real-time data collection, geo-referencing and automated reporting dashboards facilitates a more proactive and responsive approach to pest and disease management. This paper describes the implementation of a GIS-based electronic data capture system that employs ArcGIS Survey123 for use by the Biosecurity Inspectorate and evaluates the benefits and prospects for future development.

Survey123 for ArcGIS is a form-centric data collection application developed by the Environmental Systems Research Institute (Esri); it is designed to enable the efficient collection, sharing and analysis of survey data, via web and mobile devices, in both online and offline environments. Emphasising simplicity and usability, Survey123 has been widely adopted in sectors including environmental management, public health, agriculture and urban planning (Teucher *et al.*, 2022). A major advantage of Survey123 is its seamless integration within the broader ArcGIS ecosystem. Data captured through Survey123 are stored in feature layers that are hosted on ArcGIS Online or Arcterprise, and they can be connected to external Relational Database Management Systems (RDBMS), such as PostgreSQL. Using the relational data store capabilities of ArcGIS Enterprise, combined with PostGIS extensions or ArcGIS Pro functionalities, organisations can achieve advanced spatial analytics and maintain robust, scalable and enterprise-grade data storage systems (Teucher *et al.*, 2022). This architecture ensures long-term data governance, back-up and complex spatial querying.

The visualisation and analysis of Survey123 data are further enhanced by tools, such as ArcGIS Dashboards and ArcGIS Experience Builder. ArcGIS Dashboards provide stakeholders with a real-time, interactive visualisation of the survey data, which enables the efficient monitoring of the key indicators, a spatial analysis of the responses, and dynamic reporting, which does not require extensive GIS expertise (Esri, 2024). Dashboards serve a critical function in operational awareness, situational monitoring and informed decision-making. ArcGIS Experience Builder extends these capabilities by offering a no-code/low-code environment for developing customised web applications that integrate maps, survey data, analytical tools and bespoke user interfaces (Esri, 2024). This flexibility facilitates the creation of end-to-end digital workflows, from field data capture to stakeholder engagement and decision support.

From an academic perspective, Survey123 exemplifies a significant advancement in the fields of Participatory GIS (PGIS), Mobile GIS and Spatial Data Infrastructure (SDI). Its integration of intelligent form logic, enterprise-level database connectivity, real-time visualisation, and spatial analysis capabilities, positions it as a key technology for organisations that aim to develop spatially-enabled, data-driven decision support systems (Esri, 2024).

Background and rationale

The impetus for digitising pest and disease monitoring within the sugar industry arises from the inherent limitations associated with manual data collection methods. Traditional paper-based systems are frequently challenging to standardise, they are prone to physical damage or loss, and they impose administrative burdens related to post-collection digitisation. Furthermore, the absence of spatial referencing in the conventional approaches restricts the capacity to analyse the geographic distribution of biosecurity threats, thereby impeding their timely detection and the response efforts.

In response to these challenges, the South African Sugarcane Research Institute (SASRI) initiated the development of a digital surveillance system, following the centralisation of biosecurity operations within the sugar industry (Stranack, 2021). The objective was to design a user-friendly, mobile-compatible solution that enables biosecurity teams to capture data directly at the inspection site. Through the utilisation of Esri's ArcGIS platform, particularly the Survey123 application, SASRI configured a geospatially-enabled, real-time data collection system to replace the legacy paper-based workflows (Esri, 2022).

Materials and Methods

The development and implementation of a digital data collection system for pest and disease surveillance were conducted by using several key phases:

Requirements gathering and form design

An extensive consultation process was undertaken with the field inspectors, biosecurity supervisors, extension specialists, researchers, and Local Pest, Disease and Variety Control Committee (LPD&VCC) administrators, in order to document their workflows and specific data requirements. Insights from these engagements informed the design of the data collection schema and domain structures within ArcGIS Pro, which ensured a standardised approach across all the LPD&VCC regions.

The data capture schemas for Eldana and disease surveillance were subsequently published within a PostgreSQL relational database. Using ArcGIS Survey123 Connect, the forms were further customised for each LPD&VCC area, to enhance their usability and regional relevance. Regional customisations included the pre-loading of farm names and grower information, ecological zone (ecozone) classifications, biosecurity personnel lists, sugarcane variety lists, crop types and chemical (pesticide) registries.

Eldana inspection forms

The Eldana inspection form was designed to capture critical parameters directly from the field assessments. Biosecurity supervisors record the number of stalks sampled per field (typically 100 stalks), the average stalk height, as well as the cumulative length of the red-coloured damage symptoms observed within the stalks. These measurements are used in a preconfigured equation to calculate the percentage of red tissue per stalk sample, and they serve as a proxy for the extent of Eldana damage. In addition to the physical measurements, the number of Eldana larvae, Eldana pupae and Sesamia larvae found within the sampled stalks are recorded. The larval counts indicate the current infestation levels within a field, and they provide an estimate of the potential for a field to act as a source of infestation to the adjacent fields.

Disease inspection forms

The disease inspection forms are structured to differentiate the required level of detail, based on the type of sugarcane field that is surveyed, i.e. whether it is commercial, certified seedcane or approved seedcane. Field observations involve quantifying smut and mosaic incidence. Preloaded formulae automatically calculate the infection percentages based on the number of infected sugarcane stools. In addition, the forms capture information on the off-type varieties within the surveyed fields. Off-types represent a significant risk to the varietal purity, especially in certified and approved seedcane programmes; in addition, they may be a source of important systemic diseases, such as RSD, smut or mosaic, if they are carried over from a previously-infected field.

General pest and disease observations

Beyond the specific targets of the surveys, inspectors also document any occurrence of general pests and diseases that are encountered during the field visits. These incidental observations are rated for their severity, using a qualitative scale, and they are supported by photographic evidence that is captured through the Survey123 platform.

Geodatabase integration and dashboard visualisation

All field-collected data are synchronised in real time with a PostgreSQL geodatabase that is hosted within the ArcGIS Enterprise environment. This centralised storage enables the secure, structured management of surveillance data across all of the operational regions. To enhance data interpretation and to support decision-making processes, custom operational dashboards are configured by using ArcGIS Dashboards and ArcGIS Experience Builder (Esri, 2022). These interactive dashboards provide real-time visualisations of the key indicators, including inspection coverage, the incidence of pests and diseases, as well as the identification of emerging biosecurity hotspots, through dynamic maps, charts, spreadsheets and summary tables.

Data security and access management

Robust data governance protocols were implemented to safeguard the integrity, confidentiality, and availability of the surveillance data. Biosecurity supervisors are assigned submission rights, which limits their access to data entry functions only, while biosecurity managers and researchers are granted broader privileges, for data analysis and reporting purposes. Furthermore, regular automated back-ups are scheduled, to ensure data preservation and to mitigate the risk of data loss.

Results

The implementation of the GIS-based electronic data capture system resulted in notable improvements across multiple operational dimensions:

Improved efficiency

The adoption of Survey123 for data collection significantly reduces the time required for field inspections, if the conventional method is completely omitted. Biosecurity supervisors are able to complete and submit digital forms directly from the field, which eliminates the need to return to the office to submit paper-based forms. The submitted inspection data from the field is sent to the database and dashboards in real-time. This streamlined workflow facilitates faster reporting to the growers' LPD&VCCs, thereby accelerating the decision-making processes.

Enhanced data accuracy

The data quality and reliability improved markedly through the use of predefined input options, mandatory fields to ensure data completeness, as well as real-time GPS location tagging. Built-in validation rules within the Survey123 forms reduce human error and minimise ambiguity in data interpretation (Esri, 2022).

Real-time monitoring

The integration of ArcGIS Dashboards enables extension and biosecurity, researchers and managers to monitor the inspection progress and the pest and disease trends in real time. For instance, sudden increases in the incidence of smut, or the detection of new off-type varieties, could be immediately flagged for follow-up action. In addition, the Experience Builder applications linked to the dashboards allowed LPD&VCC administrators to export field data directly into spreadsheets, which eliminated the need to manually transcribe the information from paper forms and to streamline the generation of grower reports.

Spatial intelligence

The collection of geo-referenced data facilitates an advanced spatial analysis, which enables the identification of outbreak clusters and temporal patterns. This spatial intelligence supports targeted interventions, such as the site-specific application of chemical controls or the strategic deployment of resistant sugarcane varieties.

Flexibility and scalability

The modular architecture of the digital system allows for the rapid development and deployment of additional data capture forms. New modules are currently under development. The RSD application includes a number of steps, from stalk sample collection to the uploading of test results. In addition, separate applications cover certified and approved seedcane inspections and fallow field assessments, which will be integrated into a broader seedcane-tracking framework.

Enhanced collaboration and communication

The deployment of digital dashboards significantly improves the communication and co-ordination between biosecurity teams, extension specialists, researchers and management units. It is now possible to share dashboard summaries and alerts almost instantaneously, which facilitates more agile and informed decision-making. Notably, some LPD&VCC meetings have begun to incorporate live dashboard displays to guide their discussions, which indicates a deeper institutional integration of the technology. While the system rollout has already yielded positive outcomes, project implementation is ongoing.

Discussion

The development and implementation of a digital surveillance system represents a logical progression in the centralisation of biosecurity operations within the South African sugar industry (Stranack, 2021). The adoption of digital tools has introduced a paradigm shift in the collection, analysis and application of biosecurity data, with the integration of GIS technologies and mobile data capture transforming surveillance operations. This initiative demonstrates that geospatially enabled, real-time data collection systems can provide timely, spatially accurate and actionable insights to inform pest and disease management strategies.

Introducing new technology into a multi-regional operation presents a combination of challenges and benefits that required careful management. One of the most time-consuming challenges was achieving the standardisation of terminology and data collection formats across all LPD&VCC areas. This was achieved through regular consultation with all the relevant stakeholders. These interactions played a critical role in promoting buy-in, addressing region-specific concerns and fostering a shared understanding of the new requirements. Tailored training sessions and ongoing support were necessary to build confidence and competence in using the new tools effectively in the field.

A critical consideration for the future evolution of the system is its interoperability with existing industry databases and research platforms. Achieving seamless integration will enhance the value of the surveillance data for research initiatives, trend forecasting and the development of evidence-based policies. Although technical challenges remain, particularly regarding network connectivity in remote areas, the offline capabilities of Survey123 partially mitigate this constraint. User feedback has been largely positive, with field personnel reporting an increased confidence in their ability to capture and manage data, as well as a heightened sense of ownership over the quality and integrity of the information collected.

Nonetheless, continuous investment in technical support, device management and user training remains essential. Frequent updates to core domains, such as grower lists, gazetted variety databases and personnel records, necessitate ongoing maintenance and refresher training, in order to maintain operational consistency. These dynamic elements require careful planning and a flexible design, to ensure that the system remains current and reliable. As part of this process, important decisions had to be made regarding the management of different domain types, whether it is within the central PostgreSQL database for broader integration, or customised directly within ArcGIS Connect for field-specific workflows and deployment efficiency. Furthermore, robust contingency planning is required, including the provision of back-up devices in the event of equipment failure, loss or theft, in order to ensure the continuity of field operations in the event of equipment failure. To mitigate these risks, older but functional mobile devices must be strategically deployed as back-up units across all regions ensures that the field operations can continue with minimal disruption.

In addition, the extensive geospatial dataset generated by this platform presents significant opportunities for longitudinal research on pest and disease dynamics, the impact of climate variability, as well as the effectiveness of management interventions. Aggregated and anonymised datasets could also underpin industry-wide policy development, particularly about varietal deployment and resource prioritisation.

Conclusion

The digitisation of pest and disease surveillance activities within the South African sugar industry has substantially improved the efficiency, accuracy and responsiveness of biosecurity operations. By leveraging ArcGIS Survey123 and the associated geospatial dashboards, stakeholders now benefit from access to real-time, location-specific data that enhance operational decision-making and strategic planning. This initiative not only strengthens biosecurity practices within the sugar industry, but it also offers a model for similar digital transformation efforts in other agricultural sectors. Realising the full potential of the system will require sustained innovation, stakeholder engagement and strategic partnerships, which will ensure its adaptability and relevance in an evolving agricultural landscape.

References

Baiyegunhi LJS (2024). Examining the impact of human capital and innovation on farm productivity in the KwaZulu-Natal North Coast, South Africa. *Agrekon* 63(1-2): 51-64.

Esri (2022). Survey123 for ArcGIS: Modernising field data collection. Environmental Systems Research Institute.

Esri (2024). Survey123 for ArcGIS documentation. Environmental Systems Research Institute.

McFarlane SA, Zhou MM and Rutherford RS (2018). Progress in reducing disease incidence in the South African sugarcane industry. *Proceedings of the South Africa Sugar Technologist Association* 91: 70-73

Stranack RA (2021). Centralisation of biosecurity services in the South African sugar industry. *South African Sugar Journal* 105: 45-49.

Teucher M, Thurkow D, Alb P and Conrad C (2022). Digital *in situ* data collection in earth observation, monitoring and agriculture - Progress towards digital agriculture. *Remote Sensing* 14(1): 2-15.

Zhou M (2022). History and current status of sugarcane breeding, germplasm development and supporting molecular research in South Africa. *Sugar Technologies* 24(1): 86-96.