Section 4

Integrating GIS and GPS-assisted navigation systems to enhance the execution of an SAT-based tsetse elimination project in the Okavango delta (Botswana)

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ABSTRACT

Tsetse intervention using the sequential aerosol technique (SAT) was reintroduced in Botswana's Okavango delta in 2001 and 2002. Previously, only limited results had been achieved with various other techniques. For the first time in the present campaign, geographic information system (GIS) tools were used for operational planning and management of the entire programme. A complementary system of aircraft track guidance was used to ensure precise placement of the insecticide. The system also incorporated a mechanism for verification of the details of spray application. The operation was extremely successful, clearing tsetse flies from an area of approximately 16 000 km^2 over a period of two years with no observed environmental consequences.

INTRODUCTION

In northern Botswana's Okavango delta and fringes, tsetse control has been an important option for controlling tsetse-transmitted trypanosomiasis. Aerial spraying using the SAT (Allsopp, 1990) epitomized Botswana's tsetse control policy during the 1970s and 1980s. Odour-bait technology (Vale and Torr, 2004) replaced the previous SAT in 1991, yet no significant progress was made until 2001 and 2002, when the SAT was reintroduced using a comparatively modern approach (Kgori, Modo and Torr, 2006).

Improved navigation equipment — assisted by a Global Positioning System (GPS), namely the Satloc guidance system — was used to ensure accurate track guidance. Data management and decision support systems, such as geographic information systems (GIS), were also available for data integration. These proved to be indispensable planning tools.

The operation's objective remained the same: to eliminate tsetse completely. This time, however, the results were exceptionally good.

RATIONALE FOR GIS AND SATLOC NAVIGATION

Successful application of the SAT requires formulated insecticide to be applied evenly and systematically along accurate, parallel flight paths, so that a complete blanket of insecticide drifts through the tsetse habitat (Allsopp, 1990). Complete coverage of the treatment area is crucial, as is accurate and systematic planning and design of the operation in the first place. If areas are missed (as occurs with poor organization of treatment), pockets of tsetse flies will survive. On the other hand, if areas are overdosed, the environmental consequences can be extreme (Merron, 1986).

The Satloc AirStar 98 (CSI Wireless, Calgary, Canada) guidance system was used by all spray aircraft in the present campaign. In addition to guiding the aircraft, the system controlled the insecticide flow rate automatically and thereby ensured uniform application.

Why GIS?

In the Okavango delta, GIS was initially applied in support of the management of tsetse traps and targets in the 1990s through an integrated system that also involved the use of GPS and satellite imagery (Allsopp, 1998; Kgori, 2001). The system guided operations in the field by identifying potentially suitable tsetse areas and by mapping target locations as well as patterns of tsetse distribution.

Eventually, GIS became an integral part of a broader management strategy for tsetse and trypanosomiasis (T&T) intervention in the Okavango delta. It fulfilled the most essential requirement for "visual orientation" in the operational area, which is otherwise a largely inaccessible and difficult working environment. Because of the known usefulness of GIS, it seemed logical to employ GIS in 2001 and 2002 in the operational planning and management of the revamped SAT programme.

Preliminary work and GIS aid

Prior to the commencement of the campaign in 2001 and 2002, input data from routine entomological surveys as well as data relating to target locations, airstrips, tourism camps and access routes (where possible) were recorded accurately using GPS and subsequently archived using the GIS software ArcView 3.2. A base map of the Okavango delta served as a working environment on which to overlay input data. All data were projected using the Universal Transverse Mercator (UTM) coordinate system, zone 34 (map datum WGS 84). This covered the operational area in the Okavango delta adequately.

Unlike an unprojected geographic coordinate system (GCS), UTM applies a system of spatial georeferencing based on a two-dimensional transformation of the earth's surface onto an assumed flat plane. In the UTM system, spatial locations are identified from the perspective of equally spaced horizontal and vertical lines of x and y coordinates. This gives a comparative advantage to UTM-projected base maps with respect to the relaying of relatively accurate spatial georeferencing, both in the GIS environment and on the ground. The UTM coordinate system was particularly well suited to the Okavango project, because its metric units conveniently and accurately measured areas and distances.

Digital imagery of the delta, acquired by the Thematic Mapper (TM) sensor of the satellite Landsat 5, provided a visual perspective of important ecological features in the treatment area, including known habitat islands of tsetse "hotspots". The best tsetse habitats were identified as having the basic requirements of food (i.e. game) – and therefore proximity to water – and shelter (i.e. vegetation). We were concerned with only one tsetse species (*Glossina morsitans centralis*) and therefore did not have to take into account the variability of habitat requirements that might exist in other African regions (e.g. West Africa) where different species coexist.

A false colour composite image made from Landsat bands 2, 3 and 4 was used to highlight vegetation and distinguish suitably dense woodland from open sandy areas, known areas of scrub mopane (C*olophospermum mopane),* etc. The dense woodland was found mostly close to drainage lines, *melapo*[1] or, in some cases, seasonal pans. Nevertheless, suitable vegetation still needed to be differentiated from vegetation associated with permanently flooded areas of papyrus, etc., where there were no flies. To some extent the necessary data, including knowledge of the distributions of game, were obtained from experience and local knowledge. However, the GIS component provided an overlay of historical tsetse survey data (a "habitat-suitability" layer), which assisted in the identification of tsetse "hotspots". This methodology worked particularly well for areas such as Guai, Mombo, Nxabegha, Gubanare, etc.

Following guidance from digital imagery, specific ecological areas were targeted because of their high potential suitability as tsetse habitat. A working estimate of spatial tsetse distribution was then created using GIS. The same procedure was also used to target suitable vegetation. This information, along with data on trypanosomiasis distribution in cattle and horses, was then used to define areas of "potential" fly distribution. At the same time, old and new survey data were used to identify areas of "known" fly distribution. (Throughout the survey period of several years, the area of "known" distribution kept expanding. Right up to the start of the operation, flies continued to be found in "potential" areas outside the "known" distribution.)

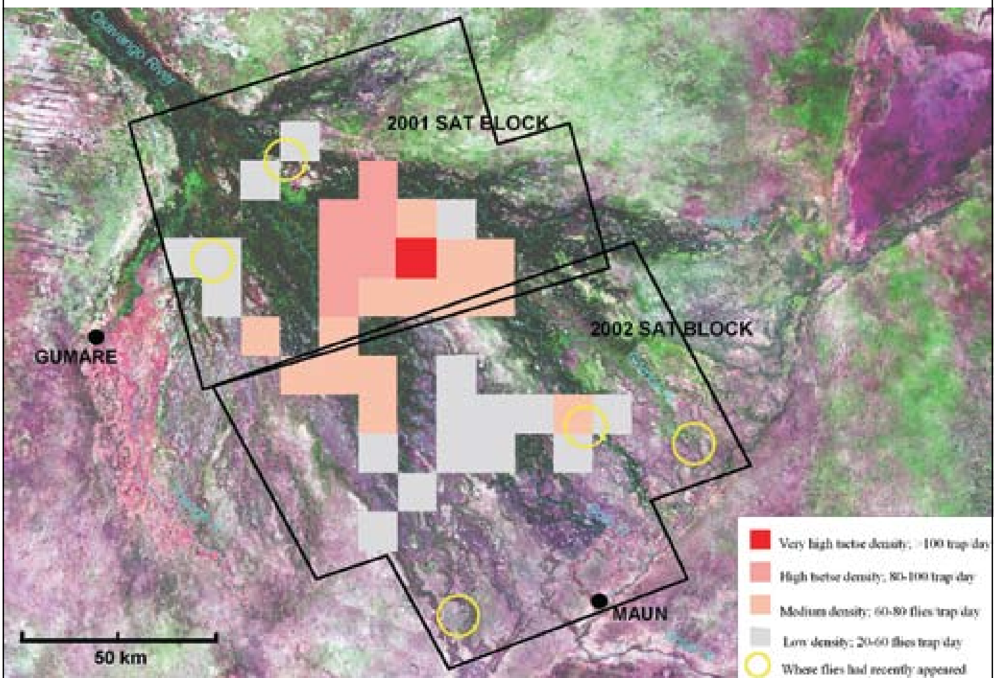
Planning and execution of the project

For visualization of the treatment area, GIS proved to be an indispensable tool. Delimitation of the project area was determined from GIS, which provided precise coordinates that were used to define each individual spray treatment area. This delimitation was based largely on a combination of entomological and parasitological data from the GIS archives. Data depicting the spatial distribution of tsetse were laid over a base map of the Okavango delta to establish accurately the georeferenced distribution pattern. The same approach was used in the evaluation of relevant parasitological data and other project planning parameters to ensure that all known tsetse infestations in the delta were considered within the strategic and operational framework of the project.

In the end, two approximately equal north and south spray blocks were identified (Figure 1), which allowed two successive operations (in 2001 and 2002, respectively) to treat the entire infestations. This approach matched perfectly the underlying strategic and environmental plan for the project, which called for no single area to be treated more than once in succession. Thus, from planning through execution of the project, the

[1] Networks of shallow, diffuse rivers.

FIGURE 1
Distribution and density of tsetse on a Landsat image map of the Okavango delta prior to the 2001 and 2002 SAT operations



technical and visual support provided by GIS was essential to maintaining the strategic focus on project implementation.

Because the northern block included areas where disease incidence was high (Sharma *et al.*, 2001), it was treated first. GIS was instrumental in the planning and management of the target barrier, following the methodology of Allsopp (1998). As a standard procedure, monitoring surveys were georeferenced using GPS and subsequently archived in ArcView for operational analysis. Incidentally, when post-spray tsetse survivors were found after the first application in 2001, it was possible to link the corresponding data to a specific locality within the treatment area using the GIS overlay. As such, only that particular area was circumscribed and singled out for re-treatment — and with relative ease.

BRIDGING THE NAVIGATION GAP

The development of GPS technology in the 1980s and its subsequent adaptation by the aerial agricultural crop spraying industry (to provide an accurate system of aircraft track guidance) signalled both improved air navigation and potential benefits for air-assisted T&T programmes. Along with automated chemical flow control, the accurate and reliable track guidance provided by Satloc GPS navigation underpinned the success of the Okavango SAT programme under review.

Satloc guidance system

Satloc introduced parallel swathe guidance that applies GPS technology to guide aircraft along predefined flight paths. Pioneered for aerial crop spraying in the early 1990s, the system, as used in the Okavango delta in 2001 and 2002, arguably represented the most significant milestone in SAT development since the operations carried out in the 1970s and 1980s.

Once the treatment area and corresponding parameters had been established, these parameters were preprogrammed using the Satloc software, MapStar. A treatable spray area was created and defined using MapStar. The system could then calculate, according to the desired swathe width, the exact positions necessary for a series of successive parallel flight paths over the spray area.

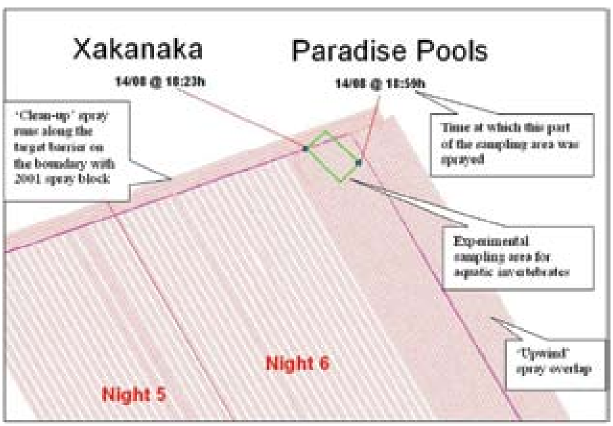
In theory, once a treatable spray area has been firmly established and the swathe size selected, individual flight paths can be flown independently yet accurately. For improved accuracy, onboard Differential GPS (DGPS) is used to guide the aircraft along its predetermined route while details of the flight path are simultaneously programmed into the system. Any risk factors that may influence the associated flight parameters may also be incorporated into the system. With Satloc DGPS, the purported accuracy of the guidance system is typically < 1 m, the most accurate ever used in SAT application.

Integrated data logger

In addition to providing accurate guidance, Satloc has incorporated a data logger that is updated every two seconds and allows flight and spraying statistics to be recorded en route. In this way, every step of the application can be subsequently verified. Using appropriate software, stored information can be retrieved on a personal computer for detailed review. The software package includes the graphic display shown in Figure 2.

FIGURE 2

GIS-derived illustration of Satloc data application in the northern boundary of the 2002 spray block showing accurate positions of the spray runs from corresponding flight logs



GENERAL OUTCOME

For effective management planning and public relations interactions with stakeholders, particularly because tsetse spraying was conducted overnight and in an area primarily used for tourism, a spray protocol for each night was developed using GIS and an overlay of anticipated flight paths. This served to provide advance notice to tour operators in the area who would potentially be affected by the spraying.

Overall, the operational results suggest that the programme was extremely successful. In just two years, tsetse were cleared from 16 000 km^2, and surveys carried out in the five years since the SAT operation ended in 2002 have found no new tsetse. In addition, no signs of cattle trypanosomiasis have been observed anywhere around the delta since 2001, and no cases have been reported from equine safaris operating in the delta. Independent environmental monitoring of the operation did not detect any long-term ecological effects (Perkins and Ramberg, 2004).

SUMMARY AND CONCLUSIONS

Previous SAT operations in Botswana and other countries in the 1970s had much broader parameters than the 2001 and 2002 operation in the Okavango delta under review here. Basic GPS technology, for instance, had not yet been developed, and accurate navigation was still a major problem. Typically, aircraft flew in formation, and pilots judged the spacing between them by eye. Furthermore, there was no mechanism for verifying the application rate of insecticide, and the operations often lacked systematic and coordinated plans.

In contrast, recent campaigns have benefited from the availability of more advanced and innovative management planning systems and strategies, including GIS applications and improved avionic technology. In 2001 and 2002, a decision was made to introduce a new generation of the SAT, enhanced by a host of effective management-support tools. Together with improved Satloc navigation, GIS made a significant contribution to the success of the campaign and thereby set the stage for future programmes to take the SAT to an even higher level of operational efficiency and effectiveness.

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Geospatial datasets and analysis techniques based on geographic information systems (GIS) have become indispensable tools in the planning, implementation and evaluation of a wide range of development programmes, including actions addressing sustainable agriculture and rural development. The growing volume of spatially explicit environmental information, combined with the widening utilization of GIS, allows ecological and socio-economic factors to be integrated more fully into the decision-making process, thus laying the foundation for a holistic approach to development.

This publication provides a cross-section of actual and potential applications of GIS in the context of interventions against tsetse and trypanosomiasis (T&T).

It aims to promote the sharing of knowledge and harmonization of methodologies among the wide range of actors concerned with the T&T problem. In the first section, a selection of geospatial datasets available in the public domain is reviewed through the lens of their possible use within T&T interventions. This review is followed by three case studies from two countries affected by trypanosomiasis (Burkina Faso and Botswana). The case studies provide examples of the application of GIS in operational scenarios and pay particular attention to data collection, management and analysis in the context of area-wide integrated management of tsetse and trypanosomiasis.

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