Geoinformatics and Spatial Data

A Forward-looking Business Plan
2015 – 2018

for

GIS/RS Section
ICT for Development Section

SPC Geoscience Division

Approved Draft

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1. Purpose

SPC's GeoScience Division seeks to maintain a reputation for excellence as the region's principal provider of geoscientific services.

This business plan aims to support the development of SPC's 2015-2018 strategic plan by focusing on avenues to apply excellence in science, knowledge and innovation in support of sustainable development in the Pacific within a geoscientific information and data context.

Pacific Island Countries and Territories are typically under-developed small island states and technology is often not on par with global developments and trends. Geoscience Division's ICT for Development and the GIS and Remote Sensing Sections aims to inform these states about the latest development related to spatial data and related information management tools and processes to ensure technology transfer.

In several instances, it is economically infeasible for these countries to invest in latest geoscientific developments and spatial data management, therefore the onus is on Geoscience Division to carry out these tasks on behalf of the member countries. For example, image data purchase and preprocessing is a highly specialised task where knowledge about the type of available image data and software to preprocess image data cannot be implemented and sustained with a Pacific Island state as the data and it's derived information product's demand does not economically justify the development and resourcing of such a unit for a government ministry within a state.

However, as centralised regional resource at the service of it's member countries, the Geoscience Division is well placed and appropriately resourced to -

- Acquire spatial and imagery datasets from global vendors at a reasonable discount.
- Undertake specialised data preprocessing using highly-skilled personnel and expensive software and tools.
- Analyse, extract and derive information products out of purchased and field-acquired data to enable decision-support within a wide variety of domain areas.
- Manage spatial data holdings and evolve related information products and systems as custodians on behalf of member countries.
- Engineer systems and tools to better determinate information products and enable decision making to enable monitoring and response to natural resource use challenge, and disaster risk reduction.

This business plan highlights planned activities which will continue to be enhanced and expanded upon for member countries over the next 3 years, while being mindful that a certain degree of flexibility is essential to keep abreast with the rapidly evolving field of spatial data technology, remote sensing and geospatial systems development (software engineering).

The business plan is donor driven and dependent on ongoing funding for implementation of hardware, software, tools, methods and related capacity building activities, and therefore can be influenced in the future by specific project donors goals and targets.

2. Organisational Context

SPC's geoinformatics ecosystem enables sound data-driven decision making pertaining, but not limited, to the following -

- Wealth generation and economic growth - by enabling better natural resource management (for example: marine mineral deposits, forest change detection, landcover use), delineating maritime boundaries and exclusive economic zones (EEZ), and expanding trade and tourism with up to date hydrographic and navigation charts.

- Improving livelihoods - by enabling better access to fresh water and sanitation (by surveying public/private water sources, freshwater lens), climate variability and change adaption, and inform mitigation efforts; for example: migration, climate proofing (for example: where to build sea walls)

- Building a safer and resilient Pacific - developing more effective and integrated ways to address climate and disaster risks, within the context of sustainable development, quantify damage and loss for financing and insurance purposes, inform urban planning, and by also strengthening disaster preparedness, response and recovery.

The underlying theme of all GSD project deliverables is in-country capacity building to ensure sustainable development, that is, member countries are aware of the hows, whys and whats of the data, systems, tools, processes and policies used to bring about the above.

3. Image Data

Image data is stratified into (i) optical satellite image data of different resolution where very high resolution is dominant of data supplied by DigitalGlobe; (ii) space borne radar data of JAXA and possibly Airbus and sentinel and (iii) LiDAR data. There is also a possibility that the processing of UAV based optical sensors will become a task.

3.1. Satellite Image Data Purchase

The purchase of satellite image data is established but will be further enhanced during the next three years. It is expected that space borne radar will be utilised in GIZ financed projects where the purchase will not be limited to JAXA[1] data only. Image data resellers will be widened to additional image data provider of niche market.

3.2. Image Data Pre-Processing of Optical Data

Image data pre-processing includes[2] (i) image stitching, (ii) haze removal, (iii) atmospheric correction, (iv) pan-sharpening, (v) geometric correction (ortho-correction), (vi) image backdrop production. It is expected that the geometric correction will be enhanced with better DSM (Digtal Surface Model) available and more precise position recording of the satellite during image recording.

3.3. Image Data Pre-Processing of Radar Data

Space borne radar data utilised at SPC-GSD was pre-processed in Europe with low resolution DSM. With available software steps of pre-processing such as de-speckle and geometric

1 The GIS and Remote Sensing Unit of SPC-GSD is already an official reseller of JAXA satellite radar data.

2 Depending on image data and demand of customer

correction can be performed at SPC-GSD. This will allow to utilise higher resolution DSM and improve the radar quality.

3.4. Analysis of Optical Image Data

The analysis of optical image data has developed from purely visual image interpretation to semi automatic analysis through object based classification with visual control. It is expected that the this type classification will be enhanced and more image classes will be separated.

3.5. Analysis of Radar Data

Radar data have the advantage that the data can be recoded through clouds and at night. Cloud cover is a problem for all atoll islands and radar data therefore have a niche in the Pacific.

The analysis of radar data will concentrate on forest structure where GIZ as funding agency is investigating in identification of forest degradation. Here the surface texture is the focus. Other applications are vessel detection as part of harbour monitoring where the outline of objects are the focus. A third application will be the fast mapping of flooded areas where the intensity of reflection

Which application can be developed during the next three years depends on funding through projects investigating in the different applications. It also depends on the availability of Pacific islanders willing to move into the new applications[3]. It is expected that open source software for radar data analysis will be freely available, however, it is an assumption that such software is sufficient to allow the necessary analysis of the data.

3.6. Capture of LiDAR Data for Land Use

Optical data allow to analyse the image colour, texture and outline of the objects. LiDAR data provide third dimension and allow to recognise the height of vegetation, the form of trees and buses and the diameter of tree crowns or bushes. LiDAR data therefore is an optimal remote sensing data set. The Geoscience Division did not invest in setting up LiDAR data analysis as the data capture was unsustainable expensive for Pacific states. With more than USD 500 per km^2 larger area covered with forest or agriculture cannot be recorded. The high cost is related to the cost of bringing special planes to islands carrying LiDAR sensors.

There is a new development that LiDAR sensors can be mounted on copter UAVs. This drops down the cost significantly. It is planned to establish a link to sensor developers to have access to this development[4]. At a further stage it is planned to test the data capture in the Pacific.

3.7. Analysis of LiDAR Data for Land Use

The analysis of LiDAR data captured over vegetation is already developed[5]. So far it is not applied in the Pacific as very limited data is available. If data can be captured at reasonable cost through sensors mounted on UAV data analysis has to be developed for the Pacific.

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3 The Geoscience Division currently is facing a situation that there is no student at USP willing to take a thesis investigating in data analysis for forest degradation, where the data and support is free through JAXA.

4 A presentation was given in April at the GIS&RS User Group Meeting in Suva demonstrating the work of the first prototype of LiDAR sensor mounted on a UAV.

5 LiDAR analysis of vegetation was demonstrated during the Pacific Islands GIS&RS User Conference by the University of Freiburg, Germany and by the company rapidlasso GmbH

Link to European universities have to be enhanced to transfer the technology and software to the Pacific. However, this not only depends on the establishment of a link remote sensing officers have to be funded investing a in this technology, where projects have to be designed.

4. Digital Surface Generation

The current land cover mapping concentrates on remote sensing data showing type of land cover such as forest, agriculture or pasture land. If this data can be combined with information of altitude, inclination and aspect the growing potential and other information can be extracted[6]. Digital Terrain Models (DTM) are available for several Pacific states, however, at 1:50,000 scale level and today's mapping scale has increased to 1:10,000 scale level. It is essential for Pacific states to have DTM ate 1:10,000 scale.

4.1. 3D Generation from Satellite Stereo Image Data

DSM generation at 1:10,000 scale using very high resolution stereo satellite images is already operational. However, the method has to be further improved limiting the necessary image reference points requiring field work and high resolution GPS to a minimum. There is also improvement possible during the next years to eliminate radar shadow through additional image of different view angles.

4.2. 3D Generation from Space Borne Radar Data

Space borne radar will increase in resolution which will provide the potential of DSM creation with higher resolution. If a radar data processing facility is installed the potential of DSM creation will be investigated.

4.3. 3D Generation from UAV Borne Sensors

DSM can be produced from optical sensors mounted on UAVs which is semi operational at SPC-GSD. However, the more interesting solution will be LiDAR data captured from sensors mounted on UAVs as this data shows the canopy and the surface and DSM as well as DTM can be established from the same dataset.

The establishment of a processing facility depends on project funding for LiDAR analysis for land use as the DSM and DTM will be a by-product.

5. Capacity Building

Capacity building is the underlying theme of many of the division's programme and project goals in order to ensure ongoing sustainability of projects by transferring knowledge to appropriate personnel within member countries and agencies.

5.1. Training in QGIS and Other Open Source GIS/RS Software

MapInfo was for many countries the first choice of GIS software as during the last 1 ½ decades it was possible to provide evaluation licenses free of charge and GIS units in the Pacific had updated software. This is no longer the case, however open source software alternatives has developed to

6 There are many applications such as potential flood mapping, wind farm location determination, safety requirements 45 km around airports, etc.

a stage that it covers all features required by GIS users in the Pacific.

There is a growing demand for training in QGIS and the Geoscience Division is aware of the needed working capacity to cover the demand. The training covers the basic functions such as (i) data input by digitising, GPS, image data or tables; (ii) production of different types of maps, (iii) linking spatial layer to external databases, external OGC web services, or (iv) overlaying and analysing different spatial layers.

5.2. Training in QGIS Customisation and Python Geospatial Development

Workshops and training are regularly held by Geoscience Division targeting member countries government ministries, partner agencies and academic institutions to transfer knowledge regarding how to develop specialised QGIS plugins and standalone data-processing applications built on the easy to learn scientific programming language, Python and it's geospatial libraries.

5.3. Training in Implementing Spatial Data Infrastructure

Highly customised workshops, trainings and manuals are delivered to stakeholders post-deployment of any SDI (see Section 8: Establishment of Regional Spatial Data Infrastructure)

5.4. Training in Database and Cataloguing

Especially in agriculture and forestry departments knowledge of database handling is missing. Databases store data more structured and more safe than the current praxis of spread sheets. There is a high demand for training to convert spread sheets to database tables although the demand is not expressed yet. The demand is in utilities but also in forestry, agriculture and environment departments. Fishery departments will follow.

The currently most utilised database is Microsoft Access as this software provides the interface such as forms, reports, etc. However, there are problems applying Access related to hidden change of libraries. During the next three years the comparative open source product LibreOffice will further develop the internal database and GIS&RS units in the Pacific will move to LibreOffice[7]. This will create additional demand for training.

During the next three years database training has to be provided. However, to be able to provide this more staff of Geoscience Division has to be trained as staff capable to train database software is currently very limited.

5.5. GPS Training

The Geoscience Division utilises and trains GPS application in three different levels (i) at 1:10,000 scale level (2 -3m accuracy) with hand held units utilising an external base station for differential correction, (ii) at 1:5,000 scale level (80 cm accuracy) with own base station and at 1:1,000 scale level (10cm accuracy) with survey grade instruments.

The training concentrates on data input and differential correction with own GPS software. Another important part is the import and editing of GPS data within GIS environment. To operate the data receiving is only a small portion of the training.

7 Currently the LibreOffice database software is not fully operational.

5.6. Data Disaster Recovery (Storage and Backup) Training

To avoid data loss data has to be structured and stored in the manner prescribed in the Data Storage section. High demand for training is anticipated in this area.

6. Data Storage

Data loss is one of the critical issues when dealing with spatial data. The Geoscience Division provides a service in structuring spatial data of the member countries and territories and storing a backup.

An common data structure is developed, however, during the next three years this has to be implemented in the Pacific. For several GIS/RS users training of staff alone will be not sufficient. There will be cases where the staff of the Geoscience Division will actually be asked to structure the spatial data.

Alternatively, Geoscience Division also provides OGC-complaint data repositories via it's Geonode and Spatial Data Infrastructure deployments regionally and within countries and government ministries.

7. Systems Development

The demand for spatial data management and related technical services is continually increasing, and hence there is a corresponding need for increasingly large databases to monitor and respond to natural resource use challenges. Demand for data/information management services also responds to the need to ensure effective information and knowledge transfer across the region.

The division's ICT for Development Section provides diverse and integrated services across the work programme to ensure that essential data management systems are operational and that the necessary support is available to underpin the delivery of the technical work programmes.

The core function of ICT for Development Section entails the development of systems, processes and tools to underpin information sharing and links across Pacific Island countries and territories and other key stakeholders, as well as providing technical advice to programmes.

7.1. Spatial Data Application Development with Open Source Software

Geoscience Division designs and implements regional, in-country and project-specific spatial data dissemination, analysis and management applications for the cloud, desktop and mobile platforms. The systems are targeted at a wide variety of users – from advanced GIS users to non-technical decision makers.

The large-scale enterprise-level systems developed by the division are built upon tried and proven open source geospatial software, more often than not in close-conjunction with the division's international technical partners working in similar arenas such as Geoscience Division.

Post-deployment, Geoscience division provides on-going technical support and ongoing evolution in the form of feature enhancements and bug-fixes. Special effort and resources are also invested in capacity building by way of providing customised workshops and trainings, along with providing related documentation and manuals. This ensures the ongoing sustainability of the deployed tools and systems.

7.2. Decision Support Tools

As the division has data-holdings collected over a four decade period, there is an ever-growing need not just to better manage them in an integrated manner, but also to contextualize them and derive information products that was not initially envisaged during the data collection inception.

The information products aim to easily enable and assist decision-making in the areas of natural resource management and monitoring, and disaster risk mitigation – and are often targeted at non-technical users in decision-making roles.

7.3. Customisation of QGIS and Plugin Development

With the advent of QGIS and other geospatial open source software adoption within regional universities, agencies and government ministries, the user requirements and needed functionalities of the QGIS and related applications needs to be fine-tuned and supported for the member countries.

This entails developing and expanding plugins built on the QGIS ecosystem, along with modifying the core QGIS application to built high-specialised desktop tools, especially for decision-support purposes.

Geoscience division holds the specialised technical skill sets to implement fairly advanced plugins to extend QGIS, and build stand-alone analytical desktops tools derived from core QGIS.

7.4. Project-Specific Web Presence

The Geoscience Division provides content and document management systems implementation to SPC projects and in-country ministries. The implementations are based on open source Content Management Systems (CMS), in particular, Drupal and Joomla.

The division has the capacity to provision advanced search and indexing capability, allowing for intuitive retrieval of content, documents (for: example in-text PDF and Word search) and data from a wide variety of sources. The division also provides Search Engine Optimization (SEO) services and advisory.

7.5. Data and Metadata Standards

Given the diverse data acquisition methods and sources utilised by the division over the years, it is fundamental that industry-standards pertaining to sound geospatial data management practices is enforced across all systems and processes developed by the Geoscience division, both internally and for member countries.

To this end the division has adopted and enforces (Open Geospatial Consortium) OGC-sanctioned standards for all geospatial content and services, GIS data processing and data sharing. In particular for metadata it enforces Catalogue Service for the Web (CSW) profile which ensures all data, regardless of data source, type and restriction is catalogued in a singular structure across of holdings and repositories.

This ensures that the regional and country-specific data holdings conform to the ISO 19115 Geographic Information Metadata standard from ISO/TC 211, which is the current best practice standard for geospatial metadata.

7.6. Software Engineering, Deployment and Associated Tools Standardisation

Given the specialised nature of the software engineering requirements (computing resource intensive) and outputs related to geoinformatics and spatial data systems, the division has adopted the following tools and platforms over the years:

Systems Development Frameworks	Spring Framework Typesafe Platform Django Web Framework Geotools and Geoserver
Languages and Runtimes	Java v. 7 and 8 Scala Clang/LLVM (C++) Python v. 2 and 3 PyQT (for QGIS and Desktop) R Matlab
Relational Database Management Systems	PostgreSQL PostGIS MongoDb
Source Versioning Control	Git
Data Versioning Control	GeoGig
Deployment Environment Targets	Amazon Web Services (AWS) Docker Containers Ubuntu Linux LTS
Build Tools	Maven – for Java Gradle – for Spring Framework SBT – for Scala and Typesafe Paver – for Python and Django Jekyllrb – for Static Websites

The above tools and platforms were adopted and standardised upon by Geoscience Division because a.) they are considered the industry-standard in the geoscientific software engineering field, b.) and therefore has ample technical support and human resources capacity in the region provided by the relevant development partners in conjunction with SPC.

7.7. Open Source Adoption and Engagement

Geoscience Division continues to prioritise, support, maintain and extend its existing open source analysis and data management tools and systems for partners and island members; and provide appropriate advocacy and support to island members in using open source technologies for ICT and geoscientific systems development.

Geoscience Division is in agreement with many of it's international donors recommendations to adopt and implement free and open source technologies for developing countries in order to ensure sustainable development.

Source code sharing ensures a development project’s longevity and survivability as external resources (such as developer time) can be engaged to provide support and expansion from the community, as and when required, in the long-term.

Geoscience Division engages proactively with the open source community by publishing in the public domain the source code of many systems development projects undertaken within the division. This gives the division an opportunity to contribute back to the open source community, from which a large number of systems within the division are built upon.

The division was an early adopter of open sources technologies, and has implemented cost-effective systems and services for the region dating back to late 1990's. SPC's governing council endorsed the division's efforts in this arena in 2011.

8. Establishment of Regional Spatial Data Infrastructure

The term “Spatial Data Infrastructure” (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general.In short it is any inter-connected set of systems, tools and processes that enables easy management, exposure and analysis of information across all spatial data themes.

SDI has the potential to be a suitable driver to derive economic benefits for member countries by leveraging collective intelligence and data across ministries and regional agencies, and additionally empowers stakeholders to make sound decision within a spatial context.

8.1. Regional SDI Implementations

Geoscience has implemented and provides ongoing technical support, enhancements and capacity building to large-scale regional SDI deployments such as PacGeo and Pacific Risk Information System. They are built to act as the authoritative open access geospatial data repository for the Pacific Region providing premier geophysical, geodetic, and marine spatial data.

Implementations are done in conjunction with international partners like World Bank, Geoscience Australia, CSIRO, University of Sydney, GRID-Arendal. The implementations are utilised by Geoscience Division staff, member countries and international partners.

The regional deployments are hosted in the cloud to counter redundancy, backup and disaster recovery issues, as well as countering sub-optimal hosting bandwidth in SPC. Additionally cloud-hosting enables multiple stakeholders remote management, and thereby promotes data ownership.

8.2. In-country SDI Implementations

Many member countries do not have optimal bandwidth to utilise the services provided by the regional SDI's, in particular consuming datasets using OGC web services. Hence, it is imperative that localised instances be deployed within member countries as a government-side service facilitate faster and easier access to their countries data holdings and information products.

Geoscience division has implemented such services, and provided relevant capacity building via workshops and trainings to a number of countries, and will eventually target additional countries, depending on funding availability.

8.3. Pacific SDI Working Group

Geoscience division undertakes the deployment of the SDI services with the assistance (in terms of funding, human resources and technical support) of a wide range of partner agencies. This working arrangement has been formalised as the Pacific Spatial Data Information Working Group (Pacific SDI WG) and currently comprises of SPC, Geoscience Australia, CSIRO, SPREP, GIZ, IUCN, and the Pacific Forum Secretariat.

The SDI working group actively contributes to:

- Deployment and Support of Country-Specific SDI, along with contributing developers and resources to enhance and evolve SDI platforms forms the region.
- Formalize regional capacity building in the way of collaborating on online course materials for QGIS and PacGeo, and generating specialised manuals.
- Work towards a CROP-wide data sharing agreement, and provide advocacy to country leaders to adopt it across the region.
- Work towards adopting and fine-tuning international spatial data standards and protocols suitable for a large geographically dispersed, ocean surrounded region such as the Pacific.

9. Applied Research

9.1. Area Calculation of Interpreted Image Data (Maps)

Map production of country wide land cover or vegetation maps have the outputs (1) the map showing which area is covered with which land use class and (2) the statistic showing the area in hectare or other units covered by each land use type. The second output still needs improvement as the current methods of transferring statistics calculated in raster environment to a relational database is not optimised yet. Here time for improvement is required.

9.2. Applying Machine Learning to Semi-Automatic Imagery Classification

Developing QGIS plugins to enable PIC GIS users to undertake semi-automatic supervised classification. Tools developed will be designed to expedite the processing of multi-spectral or hyper-spectral remote sensing images. This can be applied to detect land cover usage for forestry and agriculture, flood monitoring etc.

Additionally, training in eCognition, a propriety alternative for object-based image based classification, will be provided to member countries.

9.3. Other Research Areas

Geoscience Division's GIS/RS and ICT for Development Section is continuously looking for research areas where it can implement innovative applications and solutions to solve real-world problems applicable to the geographic information requirements in the region.

10. Inventory Support

Forest, land use and coconut resource inventories require remote sensing, GIS, GPS and database applications which are the skills of the Geoscience Division. The main database

structures and field data collection designs are developed for Pacific environment; they just need further adjustments due to new information demand and changing hard and software. The Geoscience Division works closely with SPC-LRD where a joined inventory unit was agreed and established.

10.1. Coconut Resource Inventories

The demand for coconut resource inventories depends on the world oil price level. As higher the money required for one barrel of oil as more lucrative coconut can be converted to energy and as more demand raises for inventories of available resources. It is expected that the Geoscience Division will be involved during the next three years in Kiribati, Tonga, Samoa, Tuvalu and Federated States of Micronesia.

10.2. Forest Inventories

Support of forest inventories depend on agreements Pacific states sign with resource provider for REDD+ initiatives. It is expected that the Geoscience Division will be involved during the next three years in Solomon Islands, Vanuatu and Fiji.

10.3. Land Use Inventories

In case that REDD+ tasks need carbon estimation of different land use classes the Geoscience Division is able to run inventories estimating the carbon content for grass land including shrubs and coconut plantations.

11. Spatial Information Policy

Geoscience division, in collaboration with the Pacific SDI Working Group, is working on the development of a data and information access policy in recognition of the large and increasing demand for access to scientific data and information, including the division products. The division remains committed to making its data and products as open and freely available as possible, in line with international best practice for dissemination of public domain data.

Equally, this process must accommodate the need to protect or limit certain access in recognition of, for instance, confidentiality, privacy, intellectual property or national security. Consistent also with international best practice, the division must endeavour to make its information freely available, with provision to charge only for costs associated with additional processing and administration when necessary.