SpiceUp-Geodata for sustainable pepper farming: case pepper field at Bangka Belitung, Lampung, West Kalimantan, and East Kalimantan, Indonesia

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Abstract. Pepper ("Piper nigrum L.") is one of the potential agricultural commodities in Indonesia. In the past, Indonesia was the leading producer and exporter of black and white pepper in the world. However, in recent years, Indonesia has lost its leading position to Vietnam due to instability of price, climate change and pepper farmer’s lack of knowledge on Good Agricultural Practices (GAP), resulting in low productivity, plant diseases, and difficulties with water supply. In order to tackle those problems, eight public and private organizations (Verstegen, ICCO, N&S, AKVO, VanderSat, IPB, Balittro and PT. CAN) formed a multinational partnership project named SpiceUp funded by NSO. SpiceUp aims to implement a financially sustainable information service based on geodata and precision agriculture that supports 100,000 Indonesia pepper farmers to increase their production, income, food security and reduce the inputs of water, fertilizer, and pesticides. As an initial phase, baseline surveys were conducted in four targeted areas to collect data about household characteristics, inputs and income of farmers and better understand farming practices. The baseline findings show that there is an urgent need for farmers to get access to: 1. Fertilizer advice; 2. Pest and disease advice; 3. Good Agricultural Practice; 4. Water management advice; 5. Sustainability tracing system. In conclusion, increasing farmers' knowledge of pepper culture that corresponds with GAP and inviting farmers to be able to start using information technology and satellite data in their cultivation systems will be solutions in facing current challenges because the services offered depend on the real problems.

Keywords: Pepper, Good Agricultural Practices (GAP), Geodata, SpiceUp

1. Introduction
Agriculture is a strong sector of Indonesia's economy, 13% of the Gross Domestic Product (GDP) is still provided by the agricultural sector [1]. Pepper ("Piper nigrum L.") is one of the most important types of spices among other spices (King of Spices), both in terms of irreplaceable ingredient and GDP contribution. Indonesia is one of the main countries producing pepper, well-known for its two main regions as the best pepper producer in the world, namely Muntok white pepper and Lampung black pepper. Indonesian pepper had a very important role with the ability to supply about 80% of the world's pepper needs before World War II.

In year 2000, Indonesia was still ranked number 1, but since Vietnam cultivated pepper intensely, Indonesia's position in the world market declined. This event was aggravated by the weakening of competitiveness due to the low productivity and quality of pepper [2]. The decreasing enthusiasm for
producing quality crops is also a problem in pepper cultivation. In 2015, pepper prices reached IDR 170,000, but decreased to only IDR 50,000 within 3 years. Very drastic price fluctuations make farmers give up and leave the plants without nutrition with very low productivity results. Actually, the prices issue can be compensated from increased productivity, when productivity increases, it also means that farmers' income increasing. Farmers in Indonesia face several technical problems that have caused a decline in productivity and quality in pepper cultivation such as pest and disease attacks that farmers cannot overcome, nutritional deficiencies, water management problems, poor farming practices and lack of knowledge on good agriculture practice (GAP) and the absence of sustainable tracing systems.

With growing demand, there is clear potential for pepper cultivation to grow and increase both productivity and farm income of pepper smallholders in the targeted areas. For this to happen, the above-mentioned challenges on farmer organization, cultivation techniques and knowledge on GAP, with timely information on drought, soil moisture balance, weather, and the market, need to be tackled. In line with the Indonesian government's plans for using satellite data for agriculture [3], the Dutch Ministry of Foreign Affairs through the Netherlands Space Office (NSO) initiated a geodata-based programme to improve food and water security called Geodata for Agriculture and Water (G4AW), providing a platform for partnerships of public organizations, research institutes, sector operators, NGO’s, cooperatives, satellite data/service operators, the private (agricultural) sector and transmission operators developing space for food security [4]. The SpiceUp project, one of G4AW programmes comes as a solution to answer the problems above, international partnership consisting of NGOs (Akvo Foundation, International Communications Consultancy Organisation-Southeast Asia (ICCO SEA)), spices companies (Verstegen Spices & Sauces BV (VSS), PT. Cinquer Agro Nusantara (PT. CAN)), technology companies (Nelen & Schuurmans, Vandersat), university (Institut Pertanian Bogor (IPB)) and government (Balai Penelitian Tanaman Rempah dan Obat (BALITTRO)). This project is funded by the Dutch government through NSO.

1.1. **Output, Outcome, and Impact**

The project activities lead to outputs such as an operational SpiceUp system, demonstration farms and awareness-raising among communities. These outputs will lead to the sustained use of the information service, which in its turn is expected to lead to lower use of inputs and higher productivity against better prices.

The outcomes are expected to lead to poverty alleviation in the long run, as income increases and are expected to have trickle down effects. Farmers will be more resilient and self-reliant due to the increase in income, as well as enhanced knowledge to cope with information in general and for example, variations in climate patterns.

The increase in income is also expected to have a positive impact on food security in the target areas due to enhanced food production in the areas. The table below describes the changes foreseen in the areas of social-economic development, poverty alleviation, gender empowerment, increasing self-reliance and resilience, and sectoral growth based on the indicators listed in the Sustainable Development Goals (SDGs) framework indicator global document [5]. These impacts might be influenced by factors outside the scope of the project.
Table 1. Outputs: The direct project achievements.

| OUTPUTS | TARGET | DESCRIPTION |
|---------|--------|-------------|
| Farmers (Primary Target Group) | | |
| Operational Integrated SpiceUp System | 1 | A customized system where all geospatial data needed by the services is uploaded and connected to the 2 transmission channels: Web-App and Web portal. SpiceUp services that will be developed and offered to farmers and other clients: fertilizer, irrigation/drought and GAP advice, and market or traceability information; MoV: technical reports. |
| Functional SpiceUp Services | 4 | |
| SpiceUp Trainers/Key Farmers Developed | 150 (50% women/all youth) | Trainers will support farmers in using the service and in following the advice provided by the service. Demo farms will be used by trainers to show farmers how the service is used, how the advice is followed on the farm and the benefits that result from it. Farmers that have been trained by SpiceUp trainers (field technicians, extension officers, key farmers), visited demo farms, received SpiceUp marketing or promotional materials |
| Demonstration farms set up in strategic locations | 150 | |
| Pepper farmers aware of SpiceUp Services | 120,000 (50% women/30% youth) | Farmers that have been trained by SpiceUp trainers (field technicians, extension officers, key farmers), visited demo farms. |
| Farmers and other clients have skills and knowledge on how to use SpiceUp | 30,000 (50% women/30% youth) | |
| B2B Clients (Secondary Target Group) | | |
| B2B Clients aware of SpiceUp Services | | NGOs, government, farmers groups, pepper collectors who have received SpiceUp training or marketing materials. |

Table 2. Outcomes: The Short-term/midterms (indirect) effects.

| OUTCOMES | TARGET | DESCRIPTION |
|----------|--------|-------------|
| Farmers, pepper buyers, NGOs, government and other clients use SpiceUp | 100,000 farmers (50% women, 30% youth) 500 B 2B clients | ● The number of farmers who receive various SpiceUp services that are either embedded in the farm inputs they purchase or as a result of directly purchasing the service, specified by gender and age. ● The number of B 2B clients who use SpiceUp services. Before and after comparison (% change) of litres of water used by farmers for irrigating their pepper farms; L/ha or L/kg of pepper produced and cost of fertilizers or pesticides applied by farmers in their pepper farms; cost/ha or cost/kg of pepper produced. |
| Farmers improve efficiency in using farm inputs | | ● 25% improvement in irrigation water use. ● 25% improvement in fertilizer use. ● 25% improvement in pesticide use. |
| Farmers adopt GAP and CSA | 70,000 farmers (50% women, 30% youth) | The number of pepper farmers who follow the GAP advice, specified by gender and age. |
| Pepper farm productivity is increased | 25% | Before and after comparison (percentage change) of the volume of pepper production divided by planted area. The number of pepper farmers who are able to sell their harvested pepper at better prices. Before and after comparison (% change) of the selling price of pepper produced by farmers |
| Farmers sell pepper at better prices | 10% | |
| Pepper farmer’s income is increased | 20% per farmer | Before and after comparison (% change) of the pepper farm income of farmers. |
Table 3. **Impacts**: The Long-term effects.

| IMPACT | DESCRIPTION OF CHANGE | SDGs INDICATOR* | GLOBAL |
|--------|------------------------|-----------------|--------|
| **Sustainable income security and economic growth** | Sustainable pepper farming methods promote the efficient use of irrigation water, fertilizers, and pesticides. Following GAP ensures the production of higher quality peppers that fetch better prices from Verstegen and PT CAN. All these results in increased productivity and farm income. Farming households will have more financial resources to spend on living expenses or to reinvest in the pepper farm. | ![1.1.1](no_poverty_icon.png) ![1.4.1](no_poverty_icon.png) | No Poverty ❖ 1.1 ➢ 1.1.1 ➢ 1.4.1 |
| **Sustainable food production and reduced use of inputs** | Farmers will receive specific farm advice on the right amount and/or type of input needed by their pepper farms to make their farming practices more sustainable. Unlike before, when farmers relied on traditional beliefs, generic recommendations, and guesswork in applying farm inputs. This farm advice will lead to reduced use of inputs, preventing chemical leaching, soil degradation, and loss of biodiversity. Applying the right irrigation and fertilizer also leads to more productive and profitable farms. | ![2.3.1](zero_hunger_icon.png) ![2.3.2](zero_hunger_icon.png) ![2.4.1](zero_hunger_icon.png) | Zero Hunger ❖ 2.3 ➢ 2.3.1 ➢ 2.3.2 ➢ 2.4.1 |
| **Gender equality and empowerment of women, girls and youth** | The web-app services will provide both female and male farmers access to much-needed custom farm advice. Women and youth are developed to become key farmers who will provide after-sales support for SpiceUp. The Sustainable Tracing System is uniquely focused on women who are more active in the marketing of harvested pepper, providing them with buyer information to aid them in making the best decision on who or where to sell their pepper. | ![5.1.1](gender_equality_icon.png) | Gender Equality ❖ 5.1 ➢ 5.1.1 |
| **Inclusive quality education and sustainable resilience and adaptive capacity to climate impact** | SpiceUp is based on regularly updated geospatial data. By using the service, pepper farmers, who are predominantly smallholders, can work more proactively, leaving less room for high fluctuations in productivity due to sudden climate-related stressors. Before SpiceUp, these farmers had no access to any support service for pepper farming. In the longer term, developing the skills and knowledge of farmers on sustainable farming practices improves | ![4.4.1](quality_education_icon.png) ![4.7.1](quality_education_icon.png) | Quality Education ❖ 4.4 ➢ 4.4.1 ➢ 4.7 ➢ 4.7.1 |
soil conditions, local biodiversity and water tables, resulting in greater resilience and less susceptibility to climate fluctuations. Resilience, income and food security of farmers will also be improved.

Sustainable partnerships towards more growth and impact

SpiceUp facilitates access to valuable farm advice for pepper farmers in Indonesia. It increases farmer skills and knowledge, to produce better quality pepper in a more sustainable and profitable way. This will improve the overall competitiveness of Indonesian pepper, which contributes to this impact by eventually improving the market penetration of Indonesian pepper into the EU market, thereby raising the total value chain turnover.

*based on the indicators listed in the SDGs framework indicator global document

2. Materials and methods
As the SpiceUp project will focus on the areas Lampung, Bangka Belitung, Kalimantan Barat and Kalimantan Timur in 15 districts, we conducted baseline surveys to collect data about household characteristics, inputs and income of farmers and better understand farming practices. A representative sample was drawn and focus group discussions were held to triangulate data. As indicated in the original project proposal, key data collected were general information about the type of farmers, information retrieval, farm inputs and capital. Therefore, we could obtain data household characteristics (e.g. gender), the pepper plot & map; production figures (yield and income); pepper farming inputs (water, fertilizer, pesticides use and costs); and business development (e.g. current phone use and needs of farmers). It resulted in a survey of 136 questions, 1200 farmers were interviewed in the 3 provinces, 9 districts, 46 sub district, and 99 village. There are 218,000 reported pepper farmers in the target areas of SpiceUp. The project target is to reach 50% of this number to become SpiceUp subscribers within 3 years. The baseline allows comparing end-of-project data with the situation at the beginning of the project.
3. Results and discussions

3.1. Baseline main findings
There are three main findings in the baseline survey: first, there are clear variations in the situation of the farmers in the various regions (e.g. in duration of farming, type of pepper grown, use of revenues and ability to invest, smartphone use and willingness to pay for an app or information service), this needs to have implications for the implementation of the project activities. Second, the development of the information service in accordance with age and gender should be streamlined, because different groups have different wishes and might need a different business approach (e.g. younger aged people are more likely to use and pay for a smartphone application). Third, all 3 regions show that fertilizers and pesticides advice are the most needed features, followed by fertilizer usage advice and GAP advice [6].

3.2. Current phase
SpiceUp project officially starts in mid 2018, divided into 2 phases within 3 years now the project has been running for one year, several important activities have also been running, and continue to be developed such as the construction of demonstration plots as a means of learning farmers in the field, GAP training is complete for the champion farmer. Demonstration plot that has been running and can be observed in PT. CAN field with 1 Ha total area in Namang, Bangka Belitung. SpiceUp is collaborating with ITERA Lampung in the form of joint research and demo plot development in the ITERA campus botanical garden. Collaboration with local governments and agricultural input companies is also ongoing to improve the usefulness of SpiceUp for farmers and for targeted regions. The SpiceUp mobile application is in the process of being developed and will be launched in beta at the end of 2019 with a focus on service to the basic needs of farmers such as information on pepper prices, pest and disease information, and GAP. In the future, SpiceUp is projected to be used as a marketplace for pepper commodities with a traceability system.

Figure 1. SpiceUp location at four provinces in Indonesia.
3.3. Demo plot and demo farm
The demonstration plot or demo plot is an area of about 1 ha, built to achieve specific objectives such as the application of GAP, conducting scientific research, and training sites for "champion farmers". The spice up project will develop a demo plot for each province that will become the center for research and development of the best pepper plants, for Bangka Belitung demo plot located in PT. CAN's garden, for Lampung demo plot located in ITERA University's botanical gardens. The process of pepper planting in the demo plot starts with the initial phase of land clearing, seed preparation and finally planting. Demonstration farm or demo farm is an area located in pepper farms owned by “Champion Farmers”, aiming to apply GAP, a comparison between conventional planting methods and GAP, and become a training center and pilot for surrounding farmers.

3.4. Farmers training
One of the objectives of the SpiceUp project is to help farmers get basic knowledge in pepper farming so that it can produce good plant growth and increase productivity in pepper yields. To reach 100,000 farmers, we must divide the knowledge transfer system in several layers, we divide the system of knowledge transfer based on the level of knowledge and distribution of farmers in each region so that every farmer who has knowledge can teach other farmers and have a positive influence in his area. To make this activity a success, we have collaborated with agronomists, agricultural instructors and the government, we also make syllabus and learning modules.

3.5. Data input, output, and services

3.5.1. Online apps service: fertilizer advice. Fertilization advice service is provided by IPB soil department with the help of input data from IPB weather department and balittrto. This service is expected to be used by farmers to determine the optimal amount of fertilizer for the specific location of the farmer's pepper field, the data needed as input to determine the amount of nutrients that must be provided is soil samples, coordinates of the field, elevations that have been converted into land units.
Additional data such as crop stage, climate and weather are also needed to determine how much influence the age, growth phase, rain, wind and radiation affect the absorption of nutrients and when fertilizer application should be carried out. After all input data has been collected, the data is processed and produces spatial data of recommended nutritional values based on specific locations presented in the form of maps.

3.5.2. **Online apps service: pest and disease advice.** Pests and diseases are two of the main problems faced by pepper farmers. In order to tackle these problems, Balittro will provide pest and disease advice services that has two types of information, namely static and dynamic (semi real time). Static information shows information on the types of diseases and pests that exist in pepper plants, how to prevent and deal with it in accordance with the Balittro database. While dynamic information requires actual input from farmers and is analyzed by apps what types of diseases infect farmer's land and the results are in the form of suggestions to overcome and prevent these pests and diseases. The early warning system will also automatically notify when the weather at certain times supports the growth of certain pests and diseases.

3.5.3. **Online apps service: good agriculture practice.** As advice based on GAP will determine the quality and quantity of pepper yield, Balittro will disseminate knowledge about GAP to pepper farmers through online Apps service. Before transferring the GAP knowledge to the farmers, analysis about local planting culture has to be done. The digital GAP advice will be providing for seed nurseries, planting, field maintenance, harvesting and post harvesting.

3.5.4. **Online apps service: water management.** Water becomes an important limiting factor for pepper plants, especially in Indonesia because farmers still depend on rain for irrigation, hence the productivity and quality of pepper cannot reach their maximum potential. Irrigation advice to be provided by the SpiceUp app allows farmers to know when the time of the crop is in dire need of water or excess water, and how much water is needed by plants. This irrigation advice using microwave data input from the NASA SMAP (Soil Moisture Active Passive) satellite, weather history data, pepper growth phase and soil analysis. Furthermore, farmers will get warning notifications from apps if their land is too dry, too wet or if there are potential pests and diseases related to the amount of water available on the land and also advice on what to do in that situation.

3.5.5. **Online apps service: sustainable tracing system.** Based on baseline findings, it is clear that we need different business approach to be able to increase the farmers financial awareness. Therefore, SpiceUp project will not only focus on on-farm activities, but will also concern on off-farm activity which is sustainable tracing system. This activity will be carried out by PT. CAN and Verstegen as the private sector. Building the system will require many inputs such as farmers profiles, GPS location of farmer’s field, farmer’s logbook, list of collectors, supply chain data and transaction recording to produce a transaction log. The transaction log will be processed into final outputs which are barcode of the traceability system, the story behind a product and farmer and supply chain history.

3.6. **System integration**

Service provision and system integration were coordinated by one of the partners in SpiceUp, Nelen and Schuurmans (N&S). N&S has set up a dedicated portal for SpiceUp Information Services through their Lizard platform, accessible through https://spiceup.lizard.net/. All partners have personal accounts, and are using the platform to upload their results.

All partners supply different types of data, ranging from processed satellite images to soil samples and farmer profiles. All data is integrated in the data-analysis platform Lizard. Via the secured Lizard API’s it’s possible to automatically supply the most actual data to Lizard, proces it real-time, and deliver the processed data to dashboards or the app that will be developed. After the first year of the SpiceUP project, a lot of progress has been made by all partners in the available data. The partners in SpiceUp
currently provide the following data to the Lizard platform: Historic weather data and weather predictions (IPB Weather Department), Soil moisture, root zone soil moisture and soil moisture anomalies (Vandersat), Current soil nutrient concentrations and calculated nutrient demand per growth state (IPB Soil Department), Information on farmer profiles and traceability: (Akvo Foundation and PT. CAN), GAP information (Balittro). After the data is collected in the platform LIZARD, all data is pushed to the SpiceUp server to be processed according to the user's needs. Data that has been processed from the SpiceUp server is divided into 3 parts according to the user: SpiceUp Admin Dashboard, Farmer & Buyer, and B2B dashboard.

Figure 3. SpiceUp overview flowchart.

3.7. Business models
To ensure the sustainability of the benefits of this program, the SpiceUp project must have a sustainable business model that can be applied. There are three business models that have been prepared to solve these problems: Loyalty Business Model (Direct selling from full traceable pepper farmer to SpiceUp, can be sold to third parties), Inclusive Business Model (SpiceUp is exploring to become an agent to supply Agro-input to pepper farmers), and Direct Revenue Business Model (Support new and/or existing projects with SpiceUp data and services, helping Micro Finance Institutions (MFIs) minimize the risk of non-performing loan by providing agri-tailored credit risk assessment tools).

4. Conclusions
Pepper as one of Indonesia's leading spices has a very important role in Indonesian agriculture, but this commodity is vulnerable to being abandoned by farmers. This happened because of some technical problems caused by the low basic education of pepper cultivation among farmers, and the lack of innovation that occurred in the cultivation system. SpiceUp takes its role in increasing farmers' knowledge of pepper culture that corresponds with GAP, also invites farmers to be able to start using
information technology and satellite data in their cultivation systems. Several ways have been done to reach 100,000 farmers through online and offline. Making a demo plot is the first step to creating a standard cultivation example, and a place to train farmers to practice in the field. Knowing what farmers really need is also a challenge because the services offered depend on real problems that occur, so the role of the pre-project and the baseline survey becomes very crucial. Considering the complexity of an international consortium with a remote location between partners who have various backgrounds such as business, technology, research and government, intensive coordination is needed, the appointment of routine meetings online, is recommended as a useful tool for coordination between partners and monitoring the sustainability of the project.

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