Digital Technologies for Ecosystem Services: Assessing the feasibility of relevant digital technologies for improved project monitoring, project participation and transparency

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1. About the project

The digital technologies for the ecosystem services (DTES) project aims to identify gaps and challenges in the Agua para Abancay project that can be addressed by digital technologies. In order to achieve this, the project has undertaken the following steps:

- Review the project background: As part of this activity, the team reviewed the project that was implemented by Helvetas Agua para Abancay called Bosques Andinos. This review was carried out to understand what was already in place when Agua para Abancay started.
- Review the project-related documents: Next, the project team reviewed all Agua para Abancay documents, in order to get a detailed understanding of the project. Our focus was on recognizing the project's processes and getting a solid understanding of how things work.
- Interviews: We complemented our review of the documents with virtual interviews with the project team members and other stakeholders. By taking part in the interviews, we understood what parts of the project were more likely to face challenges.
- Identification of gaps and challenges: After reviewing the documents and directly talking to the project team members, we made a first attempt at identifying challenges related to each of the Agua para Abancay objectives. Our goal was to see if these gaps could be addressed with the use of innovative digital technologies.
- Initial proposal of digital technologies: During this step we proposed an initial solution of how digital technologies can be used to solve the challenges identified in the previous step. These solutions were also linked to each of the project objectives, and we presented a range of solutions to get feedback from the Helvetas team.
- Validation of initial proposal during field visit (details of the visit on Annex I): We went to the project site to analyse the feasibility of our initial solutions and talked to the project team members about the impact of the proposed solutions. The field visit also helped to identify challenges that were not that evident during the initial steps of the project.
- Final proposal of digital technologies: The project team, through this document, will propose a set of technological alternatives that could be considered to be implemented by the Agua para Abancay project. It’s important to emphasise that the solutions listed show possible options that are evaluated along criteria.

2. Background

In this section the background of the analysed project is outlined. Agua para Abancay takes part in Abancay, Apurimac. Bosques Andinos was a project before Agua para Abancay that started participation with the MERESE and the Mariño watershed.

Bosques Andinos program

The Bosques Andinos program is the predecessor of the Agua para Abancay project, it is an initiative that worked directly with the population in the andean region to preserve the forest ecosystem. The main objective of the project was for the community to benefit from ecosystem conservation. The programme intervened in different regions, including Abancay.

In Abancay, the bosques andinos project helped with the establishment of a hydrological payment for environmental services (PES) scheme in the Mariño micro-basin. In Peru PES schemes are known as MERESE, due to the name of the legislation that regulates them: Law on Retribution for Ecosystem Services Mechanism. MERESE schemes derive from voluntary agreements that establish actions of conservation, recovery, and sustainable use of resources to ensure the permanence of the ecosystems. MERESE consists of economic, financial, and non-financial arrangements. MERESE law established two kinds of participants in the mechanism, the contributors and retributors. The contributors are people that pay a small fee to the retributors that take care of the ecosystem. It means that the contributor finances the conservation, recovery or maintenance of the ecosystem service. (SUNASS, 2020)

Among the services that can follow this approach, the Peruvian State prioritised services that have a direct impact on the population's lives like hydrological regulation and soil eruption control. Usually, the private entities in the area take part in the implementation of the MERESE as they benefit directly from the environmental services the ecosystem provides. In the case of hydrological resources, for example, they are heavy users of the resource. There are different types of MERESE, the one in Abancay is a hydrological-based MERESE.

The Bosques Andinos project helped establish the MERESE in abancay. This was designed as follows: In order to pay to the communities for protecting the resources upstream (through forest protection, ecosystem maintenance, etc.) the population of Abancay devotes a small percentage of their water bill to fund the maintenance of the water supply. The water company in Abancay (EMUSAP), collaborates with the communities that live near the water sources in different activities to conserve and recover the infrastructure, using the resources collected from the Abancay population. These activities include maintaining the streams the water goes through, building rural dams to save water for dry periods, help with the monitoring system, and many others.

In order to establish this scheme, the following stakeholders were identified:

Actor	Description

Communities	Micaela Bastidas and Atumpata are the two communities that live near the road to the higher part, they use water for irrigation and personal use.
Population	The population of Abancay city are also part of the main users of the water coming from the Rontoccocha area.
Government	The government built the cement dam at Rontoccocha and has a responsibility in terms of regulation and usage.
EMUSAP	EMUSAP is the water company in Abancay that takes care of the supply in Rontoccocha.
Agua para Abancay	The project team is in charge of enabling better communication between other actors.
Irrigators	The irrigators are members of the communities on the high part of the mountain that depend on their crops. They account for a large part of the water usage that comes from Rontoccocha.

Finally, in addition to setting up the MERESE scheme, the Bosques Andinos project also helped with the implementation of the monitoring system of the MERESE by installing the sensors and started the recovery activities in the forests surrounding the basin.

3. Analysis on Agua para Abancay project

This section describes how the project is organised and how the different activities interact. The different activities are organised under three different work components: supply, demand and governance.

Supply

The supply component is financially supported by the MERESE, which is focused on maintaining the ecosystem services in the mountain areas. This ecosystem consists of several watersheds and forests that provide around one third of the water of Abancay.

As part of the project, there are also activities related to monitoring and maintaining the water source. Eco-hydrological monitoring in Rontoccocha is an ongoing task for the Agua para Abancay project that consists of improving the capacities of those responsible (EMUSAP, MERESE-H) of the water source and collecting data from different sensors. The water provider entity, EMUSAP, is in charge of the water monitoring in the area. They work in close collaboration with SUNASS and following the SENAMHI guidelines[1]. The monitoring system they have in place consists of measuring the height from the sensor to the lowest point of the water: see photo below. From this data, the water flow can be calculated using an equation that matches the geometric shape of the barrier (triangle in this case).

There are four watersheds in the Rontococcha area, of these four, three have been involved with the restoration plan and the other one is a "control" watershed. The objective of this

[1]SENAMHI is a Peruvian government organisation responsible for the meteorological and hydrological tasks in Peru - However, SENAMHI does not directly intervene in the monitoring of these basins and streams, as they have a conventional weather monitoring station in San Antonio, a region nearby. In this station, they measure temperature, humidity, and precipitation.

method is to show the population of Abancay and the retribution mechanisms contributors that the payment system works. For this objective, collection of data is necessary and is usually done only once a month. The person in charge has to go to the four sites and collect the data every month.

The situation at the rural qochas (small water reservoirs) is similar to the watersheds, there are around sixteen new qochas in the area and only a few are being monitored. Currently, two types of sensors are used in Rontoccocha for monitoring: digital and analogue sensors.

Type of sensor	Description
Analogue	Analogue sensors are measuring equipment that don't have a way of digitizing the data. For example, a precipitation analogue sensor is a water container where the water height is measured and the measure is written down on a notebook. The analogue sensors include the totalizators for measuring solid precipitation and observation tubes for measuring phreatic levels. These metrics have to be manually measured and the data is written down on a piece of paper.
Digital	Digital sensors measure automatically and store the data in memory cards. These memory cards can then be read by a computer using a program and finally have access to the measurements on the computer. The brand of sensors is HOBO, they are pluviometers with closed-source programs.

Foto 1

Totalisator N° 1 (pluviómetro que se mide manualmente) en la parte alta de la microcuenca intervenida del SMEH en Rontoccocha

Nota. Foto tomada por Jan R. Baiker.

Analog pluviometer, page 42 (Bosques Andinos, 2021)

For both types of sensors, the person in charge of collecting the data has to walk to the physical location of the sensor with a laptop and connect it to the sensor. The data collection takes around a whole day and the transportation is in the car up until it is possible and then by foot.

All the data collected by the sensors is then stored in a database that the project is planning to use, once they have enough information, to inform the population about the results of the MERESE. The conversion of physical notes (from analogue sensors) to digital data has been delayed because it demands a good amount of time.

Demand

HELVETAS held a call to select a consulting company to implement an important share of the demand-related tasks. This call was won by Conhydra and they are now in charge of the majority of the demand activities, namely:

- Updating of the water balance in the entire Mariño basin and mapping of land use
- Community-Based Provider Integration Strategies
- Improvement of systems processes and operational management to optimise demand
- Define a strategy to reduce non-facturated water
- Propose innovations for the reuse of residual water and valorisation of the hydroelectric potential of the Rontoccocha - Abancay aqueducts

For this reason, the DTES project has not evaluated the challenges faced by this project component.

Governance

The main objective of this project component is enabling better communication and sharing key information between the different actors of the project, including irrigators, community members, general population, regional and local governments and the water provider. Other activities within this component include strengthening the integrated water resources management committee, carrying out a risk analysis and carrying out contests to encourage efficient use of water.

As part of the project outcomes, the project team created a platform conformed by representatives of the public sector, private sector and civil society, among others. The (no-digital) “platform” allows stakeholders to interact with each other in topics concerning the project, namely the comprehensive management of water resources in the area. To communicate with each other they used tools like Zoom or Meets during the pandemic and now everything is on-site. Meetings are held the first Tuesday of each month and a member of each community (Atumpata and Micaela Bastidas) participates.

Currently, the way they incentivize the participation of stakeholders in the project activities (besides the platform) is via contests. For example, HELVETAS hosted a “good practices” contest to encourage local social organisations involved in the irrigation process to help with the infrastructure maintenance process. The project's work consisted of determining a baseline of the water channel conditions and measuring the channel upgrade after the contest. Around 16 irrigation communities participated during the five months the contest lasted.

Nowadays, the HELVETAS team is planning to host a contest for water use optimization. This activity is a way to get a large number of people to participate in a training about water use efficiency. In this particular case, the contest is oriented towards women, who, it is believed, are usually closer to water management, and it’s going to train them for water use efficiency.

These contests are the team’s way to incentivize the optimal use of water in the Abancay region. They plan to monitor the water receipts and analyse the optimization via the price change. Participation was low in the last contest and they are trying to make the next one more successful.

4. Gaps and challenges, solutions and recommendations

This section describes the different challenges that the project faces that could be addressed by using new technologies. The challenges are presented by work streams: supply and governance.

Challenges with the supply workstream

Physical collection of data from sensors

The first challenges identified were the lack of connection between each of the water sensors, and the fact that every sensor has independent information about the basin it monitors. This presents a series of problems:

- First, the data from the sensors have to be collected manually. Jan Baiker said that "the process consists of going to collect the data manually to where the sensors are installed, it takes approximately one day [1]" Additionally, whoever is in charge of the monitoring at the time, has to make a field visit to every sensor in every basin and connect a laptop to it. Therefore, a whole day is spent walking to the sensors at 5000 m.a.s.l.
- Second, this process implies risk of data loss and unavailability. Since the sensors are only checked when the team physically visits them, they don't have a constant status on the sensors. This means that when the sensors run out of battery or stop working no one realises this until the next visit.
- Regarding the quality of the data, HELVETAS has highlighted that its precision and reliability may be or become a problem. This is because the sensors (Onset 3g-m) are old and do not measure the precipitation precisely (the precision estimation was calculated by comparing real values to the ones collected by the sensors). Also, there is no way to find out how precise the sensors are because they do not have another brand or system to compare them to.

In short:

Collection process	The collection process is a challenge because a team member has to physically go to the sensor, remove the memory card and load the data onto the laptop program.
Precision	The precision of the hobo sensor is not the best because they are not of the best quality. They provide the project with a reference but are not 100% reliable in terms of accuracy.
Reliability	The sensors rely on a battery for power, this means that the battery can run out at any moment. And, because they are not connected to a network, the team does not find out until the next time they collect the data (which may imply weeks of data loss)

Proposed solutions

In order to address the problem identified above, it's proposed to use a technology that allows connecting the sensors to a network provider and to provide remote access to the information and controls from the operation centre. First, the sensors need to be connected to a network that works in rural areas and programmatically update the sensors, so they are compatible. Danny: "We have proposed to the consultant (Demand objective) that they implement a SCADA (Supervisory Control and Data Acquisition) system in the lower part (demand) and we plan to propose that they do it in the upper part (supply) as well."[3] This means that the agua para Abancay team is aware of the benefits that a connected monitoring system could bring to the project.

Improve the data monitoring by sensors to tackle precision and reliability

The DTES worked on a document regarding the requirements for the sensors Agua para Abancay is planning to buy. These requirements include for them to be open-source, connectable to a network, low battery usage, among others.

Improve the interconnection of the sensors to avoid physical collection of data

The first recommendation would be to interconnect the sensors with each other and with a control central. This can be done in a number of ways; each solution has their benefits. What they have in common is that a network must be available to each sensor located on the watersheds, the sensors have to be able to send data in this network and it can be powered with a feasible power supply for the area.

Technology	Scope	Electricity Power	Pros	Cons	Price
LoRa	LoRa (short for Long-Range) enables very long-range communication of more than 7 km in some areas, while consuming little power.	Consumes little power, could be solar	Range, speed, peer to peer	Requires an antenna	Expensive
Sigfox	Alternative to LoRa network. The only difference is that sigfox is one-directional. Only the sensors can send data to the central but not the other way.	Consumes little power, could be solar	Range, speed, peer to peer	Requires an antenna, one way.	Expensive
Satellite internet	Internet provided by a company that has satellites to send the wi-fi. It has great range and good availability.	May be of high-power usage	Fairly low cost, easy to implement, range, speed.	Dependent on power, Wifi integration to the sensors	Mid
BLE	BLE stands for Bluetooth Low Energy and it is designed to transmit/receive small	In many cases, Bluetooth LE products are powered only from	Speed of transfer, low energy use	Range, it would need a lot of signal extenders	Mid

	amounts of data on a fairly infrequent basis, all while consuming extremely low amounts of power.	a small coin cell battery. If data is only sent infrequently, a BLE device running from a coin cell battery may have a battery life of a year or longer.			
Zigbee	Zigbee is another short-range, networking technology similar in many ways to Bluetooth LE with similar applications. It uses the same 2.4 GHz carrier frequency, operates over a similar range, and offers mesh networking.	Consumes little power, usually batteries	Lot of devices can be connected, speed, and low energy use.	Range, it would need a lot of signal extenders.	Cheap
Z-Wave	Z-Wave is a proprietary wireless technology that primarily competes with Zigbee and BLE in the home automation market. Unlike BLE and Zigbee, which use the popular 2.4 GHz band, Z-Wave instead uses a sub-1GHz band	Consumes little power, usually batteries	Increased range and reduced interference (Compared to the two previous solutions)	Range, it would need a lot of signal extenders	Expensive
GSM / GPRS	GSM (Global System for Mobile communication) is used for data transfer and has been the most commonly used cellular technology for products that don't require large amounts of data transfer	Intermediate, usually powered with a battery	Low cost hardware	Dependent on availability, fairly outdated	Mid
LTE	LTE is a 4G cellular technology that supports much faster data speeds than GSM. If your product requires very fast cellular data transmission speeds, then LTE is likely the best choice.	Intermediate, usually powered with a battery	Speed, more expensive than GSM	Depending on availability	Cheap
NB-IOT	NB-IOT is a cellular technology. This means it is more complex, more expensive to implement, and consumes more power. NB-IOT is only intended for transmitting very small amounts of data.	Intermediate, usually powered with a battery	Higher quality cellular connections and direct access to the internet	Availability, probably won't be available at the project zone for the coming one or two years	Cheap

After getting the data to a central location, the project would need a way to manage it and standardise it so the data can be moved and used in real time. Currently, the Helvetas team uses the HOBO proprietary software and does not have an adequate way to share it.

Solve interconnectivity between sensors

Technology	Scope	Price	Pros	Contras
Water-based MQTT network	MQTT is a standard messaging protocol for the Internet of Things (IoT). It is designed as extremely lightweight. It acts as a broker between the data source and the access point to it (like a cellphone)	Cheap	Ensures message delivery, lightweight and can support a battery	It's not easy to develop in it and it depends on the power capacities of the device it is running on
REST	Representational state transfer (REST) is a protocol for communication between machines, for IoT it uses the HTTP protocol that relies on TCP/IP connections.	Cheap	Scalable, easy to use	It does not store state information, may be insecure and IoT is not it's main purpose so it may limit functionality
XMPP	XMPP is the open standard for messaging based on the XML language	Cheap	Secure, reliable, open-source	XML streaming is inefficient

Now that the project would be able to access the data and process it, it needs to properly store it for future use. This can be done in a database that has a large number of options, we present some of them that we think are most fitting for this use case.

Solve data management and access issues

Technology	Scope	Price	Pros	Cons
MongoDB	MongoDB is a non-SQL database management system that uses JSON type documents to store data	Cheap	Allows any context, real time analysis, and has a dedicated IoT system	It is not good to work with data, generally just to store it: Transactions. Join. Indexing
InfluxDB	InfluxDB is a time series database for optimising and handling time series data. It is also no-SQL	Cheap	Easy to use, open source, time-oriented	It is not good to work with data, generally just to store it: Transactions. Join. Indexing
PostgreSQL	PostgreSQL is a SQL database, but it is fast and scalable, and also has a good open source community	Cheap	Good to work with data, easy to interconnect, SQL based	Not as fast as Non-SQL, hosting may be expensive, only relational
RethinkDB	Open-source, no-SQL JSON based database	Cheap	Real time control over data	Own command interface, limited primary key.

Recommendation

Having in mind the technological alternatives presented above, the team identifies **LoRa and Satellite internet as the two best options for connecting the sensors**. This is more in line with the project needs due to two specific aspects: distance between sensors and land conditions. The main reason is that other technologies favour speed in low range settings and work with more energy. For the case in Abancay, the need of a network with good range and speed is not the priority. If the Agua para Abancay project decides to go with a LoRa network, they should have in mind that this implies buying an antenna and maybe some repeaters. This being said, the LoRa network would most likely be a one-time cost in contrast with the satellite internet in which they would have to pay each month or for what they use.

Our preferred option for the sensor data management is the **MQTT network**, it's the fastest, easier to work with and it's adequate for the project needs. The other two options were not developed for IoT, which means they do not have integrated software that allows easy development. Also, because of this, processing and preparing information would imply more work compared to the MQTT. The MQTT could be hosted in a micro-computer like a Raspberry Pi.

Finally, the preferred alternatives for the database are **InfluxDB and PostgreSQL**, these two have a difference between how they store and access the data. PostgreSQL has the advantage of being completely open source and has a nice administrator called PgAdmin that is also free. On the other hand, influxDB is a cutting edge No-SQL database developed with time-series in mind, which meets our purpose perfectly. They present the best option for each of their storage ways: PostgreSQL (SQL, structured like a table) and InfluxDB (No-SQL, time series). Even though we reduce the proposal to the two best options, the final decision would be better made with access to the data and a clearer idea of the uses for it.

See annex 2 for more detail.

Lack of information about water availability and present or futuer risks

Currently, there is no way for EMUSAP and the Abancay population to anticipate water scarcity. The only source of information is the "normal" cycle in a year and given that this information is not reliable it becomes hard to take action. If EMUSAP and the communities could be more certain that a water shortage is coming, activities and incentives would help manage the crisis.

"When the rain comes, we can deposit water there and in times of drought use it to irrigate our farms, our products, to irrigate our pastures and thus to maintain our animals."[4] (Bosques Andinos, 2021). A farmer of the Ccerabamba-Andina community explains that they have to find a way to save water when there is rain to guarantee irrigation and watering of livestock.

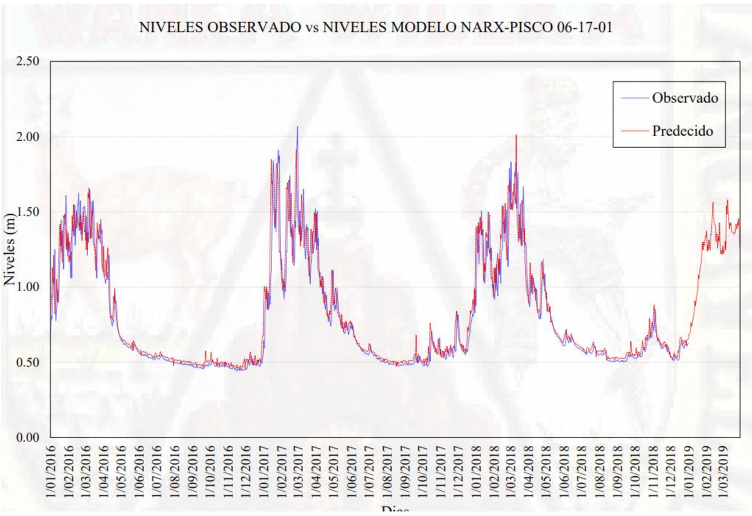
When talking to Hernan Ibarra (Supply component manager at HELVETAS) about water disponibility, he mentioned that the rural communities usually know that rain and water availability are seasonal. This implies that the communities have a very rudimentary perception of the weather and are susceptible to phenomena without anticipation. And because the information is not being shared, systems to alert the population or any application that relies on information can't be developed.

Proposed solutions

This solution depends on the reliability of the data obtained by the sensors. Once a good framework is achieved, this information would become valuable. With the data collected from the sensors, we would propose a model to predict when a drought will take place and send early alerts. Using time series forecasting, an artificial intelligence subset, Agua para Abancay could use the historical data from the sensors to train different AI models and use them to generate predictions. These models use the underlying patterns in the data to generate their targets. This characteristic is particularly useful because water availability has a high level of uncertainty.

The idea to forecast water availability is only feasible once the data is available. With this, an early-warn-system and useful forecasts could be implemented. For this, collaboration with SENAMHI and their monitoring station in Abancay is key (SENAMHI is in charge of early alarm systems in every city that has one).

There is an extensive amount of literature about this solution. Oré Cayetano, R. (2019), for example, proposes a set of neural network-based models to predict river flow and precipitation. The author achieves very high accuracy by combining data from physical sensors with remote sensing to feed the models. Here, a graph on how the predictions would look is presented:



90 day ahead prediction of water level, page 85 (Oré Cayetano, R. 2019)

In the next table, some water forecasting alternatives are introduced.

Models	Description and solution	Complexity	Pros	Cons
Classic Statistical Models	Models like regression, ARIMA, SATIMA, etc. They don't use machine learning techniques and are fairly simple. They can have good results in some cases.	Low	Easy to implement and adjust, easy to re-train	Not very good depending on the data
Simple machine learning models	These models are like a better version of regression, they usually use a technique called Gradient Descent that allows them to optimise results.	Medium	Can give good results, not much data preparation	Depending on the data quality, optimization and re-training can be expensive
SOTA Models	State of the art models include LSTM, Deep Neural Networks and Transformers. There are probably not a lot of already developed applications with this use case since the models are really new.	High	Could lead to good predictions, scalable, not much data preparation	Can be expensive to train. Depends on the amount of data
SOTA + External Data	We could try to introduce data from other sources and use it with good models and evaluate results.	High	It could be a great application for replication. Something interesting to investigate further.	Can be expensive to train. External data processing may be a lot of work.

Recommendation

For the case of Agua para Abancay, we would suggest using the last model in the table, as it is the most complex one in terms of development: **SOTA+ External data**. Even though there is a small chance that the models won't predict sufficiently accurately the water availability, this option is the most fitting for the need due to the real need of reliable predictions and the accuracy this option may offer. The predictions must be good enough to share and understandable so that the population can read them. Artificial intelligence models feed and depend on data, so if the data is not good enough, even the best model won't be able to predict accurately. For this reason, a model could only be selected when the data architecture is decided in order to maximise the performance of the model.

Challenges with the governance workstream

The Governance component is managed by Rosaura Villafuerte (HELVETAS) in collaboration with several local institutions (EMUSAP, CEDES, ANA, etc.). This component is regarded as more complex than the supply and demand components due to its broadness and its non-technical nature. The DTES project has identified three key challenges faced by this component, namely: 1. Irregular access to project stakeholders; 2. Lack of means to share relevant information; and 3. Lack of information to be provided to the audience.

Lack of participation and exchange

In terms of irregular access to project stakeholders, currently communication with communities takes place through WhatsApp groups, which reaches 70% of the stakeholders as not everyone has access to that technology. For the remaining 30%, communication takes place over the phone.

Lack of awareness about water

The lack of fluent channels of direct communication between the actors also presents a challenge in regard to divulgation **(challenge 2)**. Agua para Abancay will soon host its second “contest” where they want to promote water use efficiency, and they are currently evaluating different alternatives to reach people, as the first contest was not fully successful in terms of participation.

Agua para Abancay has tried to divulge their work and vision through different ways, including a tour called the “Yaquq Nan” (The Water Path) that takes a group of people to the different interventions areas of the project, located around the city and the high parts of the mountain. However, until today less than 40% of the population of Abancay knows where their water comes from. (EMUSAP)

Lack of information according to water scarcity

Finally, the project also faces a challenge regarding how to share the information acquired during the life of the project. Neither the population, the irrigators, the members or the community or the Academia has access to the data from the watersheds. Right now, it is stored in a database and notebooks and has not been analysed, processed or shared.

The most important information to be shared are

- Information about the impact of MERESE in the supply of water
- Information about water availability
- Awareness of where the water comes from
- Awareness of water use efficiency
- Information for development or studies

Proposed solutions

Improve access to project stakeholders

Technology	Description and solution	Pros	Cons	Responsable de la actividad	Feasibility after field trip
SMS	SMS (Short Message Service) is a text messaging service component of most telephones. It allows mobile devices to exchange short text messages.	Fast, only requires a telephone number,	Each SMS has a cost, so the more SMS we send, the more people join the SMS group, the more	Rosaura and CEDES	Most of the actors have access to a cellphone that can support text messages. Great for sending

	It could be used for a reminder of meetings, coordinations and complaints.		expensive it becomes.		alerts that require immediate action.
Email	Another easy to use notification system, and something that is cheaper to use than SMS is the use of emails. Even a Newsletter could be implemented. It would help one-to-one and many-to-many communication.	Could create a Newsletter, schedule calls or meetings.	Usually slower than more direct methods, need a laptop or smartphone.	Rosaura and CEDES	This would require a smartphone or laptop so it's only feasible for communication between institutions.
Push Notification	Push technology or server push is a style of Internet-based communication from a central server to a set of devices. It could be used to send alerts, meeting reminders, payment requirements, etc. It is a good way of massive communication but may be a bit invasive for everyday use.	Fast to reach a big group of people, basically free.	It requires a smartphone (Android, iOS) to receive them. A simple one such as a Nokia will not receive them. Harder to implement. It requires an internet connection (2G, 3G, 4G, WiFi)	Rosaura and CEDES	This would require a smartphone or laptop; it could be an option for an alert system.
Facebook	The Facebook Platform is the set of services, tools, and products provided by the social networking service Facebook. A Facebook group could be created to discuss topics regarding water, where people could upload posts and feedback.	Good groups feature free many-to-many communication ,good marketing.	It requires an internet connection (2G, 3G, 4G, WiFi)	Rosaura and CEDES	This would require a smartphone or laptop. So only a portion of the actors could take part. Still, this may be a very interesting solution.
Whatsapp	Whatsapp is the main text communication service in Peru. It could be used on a one-to-one basis or a many-to-many. The project has already created a whatsapp group with some representatives to make communication more fluent.	Good groups feature free many-to-many communication .Used by everyone.	It requires a smartphone (Android, iOS) to use.	Rosaura and CEDES	They already have a Whatsapp group, it would be a matter of creating more for different functions and getting more people into smart phones.

Implement a suitable strategy to share relevant information and increase knowledge among the communities about water issues

Technology	**Description and solution**	**Pros**	**Cons**
Facebook	The Facebook Platform is the set of	Good groups feature free	It requires an internet

	services, tools, and products provided by the social networking service Facebook. A Facebook group could be created to discuss topics regarding water, where people could upload posts and feedback.	many-to-many communication,good marketing.	connection (2G, 3G, 4G, WiFi)
TikTok	TikTok is a short form video social media. Primarily a young female audience. Posting videos on tips and tricks about ways to save water, informing people in 30 second clips.	Very direct, easy to generate content	Not for everyone, specific audience
Instagram	Instagram is a social network based on photographs and the most used in the younger generations.	Easy to make content, good reach	Not for everyone, specific audience
Youtube	YouTube is a social network based on videos. In here the project could present their work, inform the population in video, make tutorials, etc.		Longer content, not so much exposure.one communication
Push Notification	Push technology or server push is a style of Internet-based communication from a central server to a set of devices. It could be used to send alerts, meeting reminders, payment requirements, etc. It is a good way of massive communication; it could be a way of communicating the results of the model proposed in the supply section.	Fast to reach a big group of people, basically free	It requires a smartphone (Android, iOS) to receive them. A simple dumphone such as a Nokia will not receive them. Harder to implement. It requires an internet connection (2G, 3G, 4G, WiFi)

Process information to be provided to the local stakeholders

Technology	Description and solution	Pros	Cons
Analytics	Analytics is the systematic computational analysis of data or statistics. It is used for the discovery, interpretation, and communication of meaningful patterns in data. Analytics could be used to gather the information form the sensors when it’s already processed and get some insights on the data. Graphs showing metrics like supply increase, precipitation and temperature could be useful.	If the data is prepared, analysis is fairly simple. Good graphs can communicate complex ideas.	Depends on data quality, still in need of divulgation.
Website	A web application (or web app) is application software that runs on a web server, unlike computer-based software programs that are run locally on the operating system (OS) of the device. A web could be a way to integrate all uses of information into one place. Like uploading forecasts, publishing the data,	Flexible solution could be used for a number of things. Straight-forward to implement.	Depends on the user's access to the internet and may get too complex if it has too many applications.

	and real time access to information. A website is a tool to develop a solution, it is up to the Agua para Abancay project to decide what application they want to give it.		
RSS feed	RSS (RDF Site Summary or Really Simple Syndication) is a web feed that allows users and applications to access updates to websites in a standardised, computer-readable format. A simpler way if the main purpose of the website is to just publish information. standardised content generation for all social media.	Good way to publish and disseminate information across platforms (social Media, news aggregator, blog etc…)	Read only, not very human friendly.

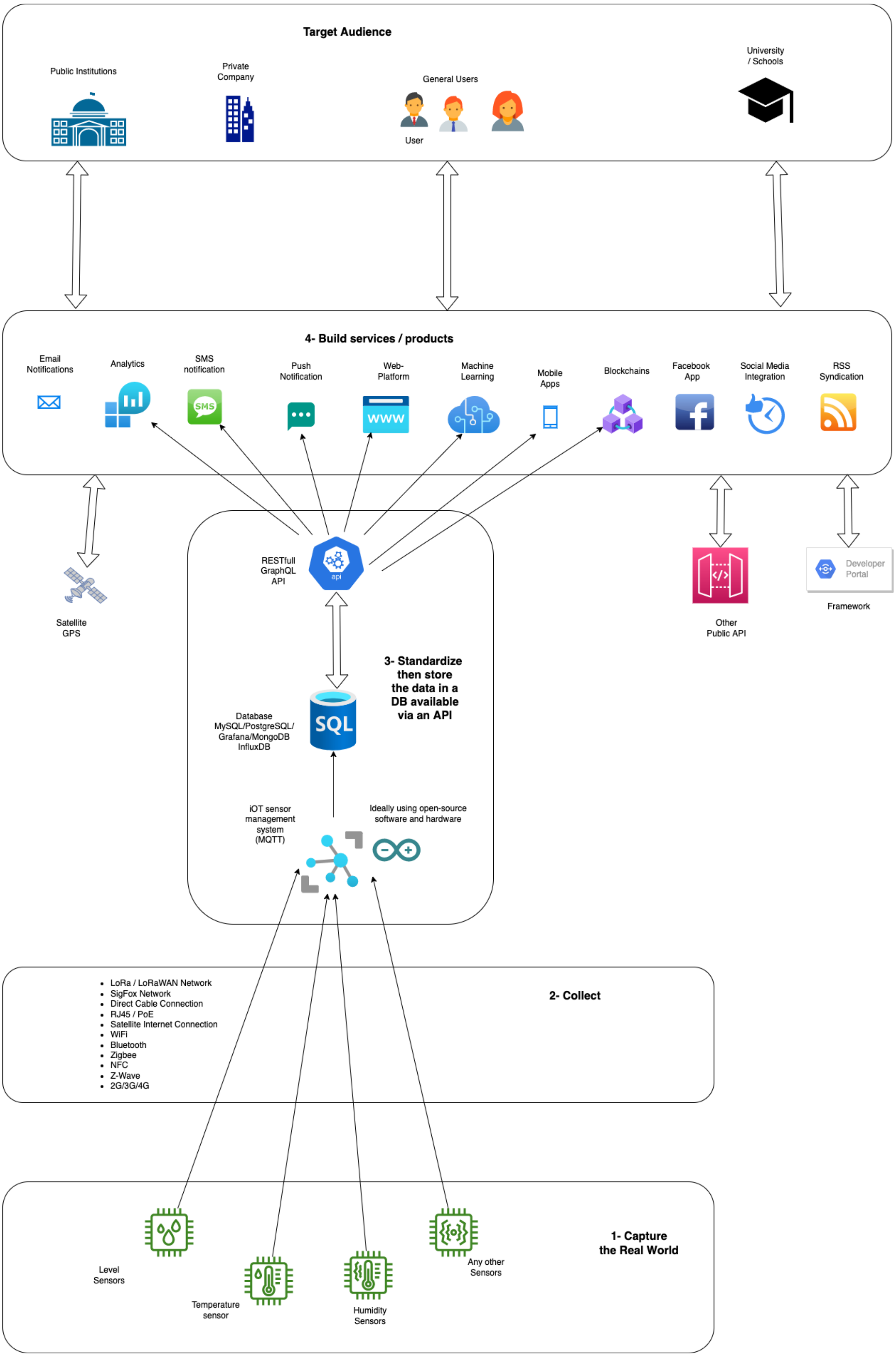
Recommendation

For the problem regarding irregular access to all the actors, we recommend creating a Facebook group where members can interact. It is true that a percentage of the actors do not have access to a smartphone or laptop. But a group of representatives could be trained to interact with the group and speak for whichever actors they are in contact with. For this contact, we suggest trying to use **SMS** more. Especially with people who do not have a smartphone, this would make them get used to texting and make the transition to Whatsapp easier.

For the challenge regarding lack of a suitable strategy to share relevant information it is suggested to analyse the situation by a digital marketing expert (Social Media Manager). It would be advisable to first conduct a survey among communities regarding their access to different social media. After that, depending on the current objective, the expert could decide which method to use. In any case, it is suggested to use **Youtube** to upload videos regarding water use efficiency. Recording the water efficiency use could be a way to generate valuable content that has an impact.

Finally, regarding the lack of information to be provided to the audience, the most important part is to finish processing the data. It is suggested to focus on getting the information processed and then apply the solutions. The solutions include **Analytics**, as a direct way to extract insights from the data. And a **website** where raw data could be accessed for academic purposes and of course a number of different applications. Real time access to information or forecasts are also a very interesting option but not considered a priority.

Proposed whole architecture



5. Conclusions

The Helvetas project Aguas para Abancay has the aim to guarantee the future availability, provide equitable access and strengthen the responsible use of water for the population of Abancay and its surrounding communities. The project supports activities such as protecting, restoring and managing ecosystems where Abancay's water source is located, applying a sustainable investment mechanism and optimising the demand for water in the city by monitoring and controlling water losses and raising awareness. Furthermore, it aims to strengthen and consolidate the governance spaces for the management of water resources.

The CLI funded DTES project aimed at analysing the gaps and challenges of the Aguas para Abancay project in the field of monitoring, participating and transparency and identifies the potential to overcome these challenges by means of innovative technologies. The assessment examines the potential of innovative IT approaches, such as smart phone (apps), IoT, AI and blockchain for improving processes of project monitoring, project participation and project transparency.

Rather than to see these challenges as a deficiency, we examined them in order to identify potential digital solutions (see table below). First, regarding supply, we identified that the data from the sensors must be collected manually, which decreases the data reliability, access, etc. For this challenge we propose an interconnected network which allows to collect and store data remotely. Another problem identified is the lack of interactions between the sensors. As a consequence, information is so infrequent that the population is not well informed about water availability. Therefore, a real time access and a model to generate forecasts is proposed. Secondly, there are three main challenges identified in the governance pillar; Lack of participation and exchange (how could one increase the goal of saving water), lack of awareness about water (where does the water come from, what are the benefits of my payments to the MERESE?) and lack of information according to water scarcity. For these reasons, we present a variety of technologies for enabling communication, like social media and SMS. And then a good way to structure it with analytics and a general website.

What is important to notice is that whatever options are considered for implementation, they need to be accompanied by a series of training. This is needed to help and train stakeholders with the required mechanical repetitive work and maintenance of the infrastructure.

Overview of conclusions

	Gaps and challenges	Description of possible solutions	Suggested technologies
Monitoring	• Data accuracy due to sensor quality • Collection process is a challenge, long distance walks to the monitoring site • Low reliability of data series, as sensors rely on battery work	• Apply sensors with better accuracy • In order to provide a remote access to the information and control the data from an operation centre, an interconnection of the sensors could be applied • Apply a technology to manage and standardise the data in order to use it in real time. • Storing the data in a database (MongoDB, InfluxDB, etc.. • Explain on a low-profile option	• Which Sensors could be applied? • LoRa or Satellite internet • MQTT network • InfluxDB or PostgreSQL • collecting the data using pen and paper
Participation	• Lack of participation and exchange among communities and stakeholders • Lack of engagement among communities and stakeholders	• Implement platforms and services for better coordinating meetings, sending alerts, inform on payment requirements, discuss topics, receive feedback, share best practices on e.g. water savings.	• Facebook, SMS
Transparency and awareness	• Lack of awareness about water (where does the water come from) • Lack of information according to water scarcity	• Showing how payments for MERESE provide impacts • Showing tips and tricks about ways to save water, inform people and provide tutorials, • Data modelling according to the sensor data, train different AI models and use them to generate predictions and use push technology or server push for massive communication	• Youtube • Analytics, Websites, push notification (harder to implement)

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Annex I: Field visit

From May 16th to 19th, representatives of the DTES project, Michael Fabing and Francesco Uccelli, visited Abancay to get a closer look at the Agua para Abancay project and analysed the feasibility of the proposed solutions. The visit consisted of three days and was mainly focused on having additional interviews and visiting the watersheds where the Agua para Abancay project is located. The first activity was a meeting with the project coordinator, Marco Sotomayor. During the interview we talked about some of the challenges they face regarding project implementation and some of the current activities.

Three main challenges were identified in the meeting with Marco Sotomayor:

- Lack of knowledge about water supply: The main challenge Marco Sotomoyor identified was the population's lack of knowledge about the water supply. They estimate that only around 40% of the people living in Abancay know where the water they use comes from.
- Lack of participation due to informal settlements: Marco also mentioned that the increasing population of Abancay is mainly informal, which makes it even harder to integrate them into the water network.
- Finally, he mentioned that there are some problems with the EPS (EMUSAP) and the communities because they are refusing to pay the fee that was established for the integration of the communities into the water network which includes the water feed and the MERESE fees. This is mainly because the communities would like to stay informal and don't have their water use regulated.

On the second day the team, together with Sandro Arias (Helvetas), Hernan Ibarra (Helvetas), Danny Saavedra (EMUSAP) and others, visited the higher part of the Mariño basin. The purpose of visiting the higher part was to get a better view of the landscape, to see if sensors could be connected to each other, understand the geography of the zone, and get to know the processes taking place in the area. The group followed what the Helvetas team calls "Yakuk Ñan" (the water path), which consists of ten different stops that range from the highest watershed to the lowest part, the water treatment plant.

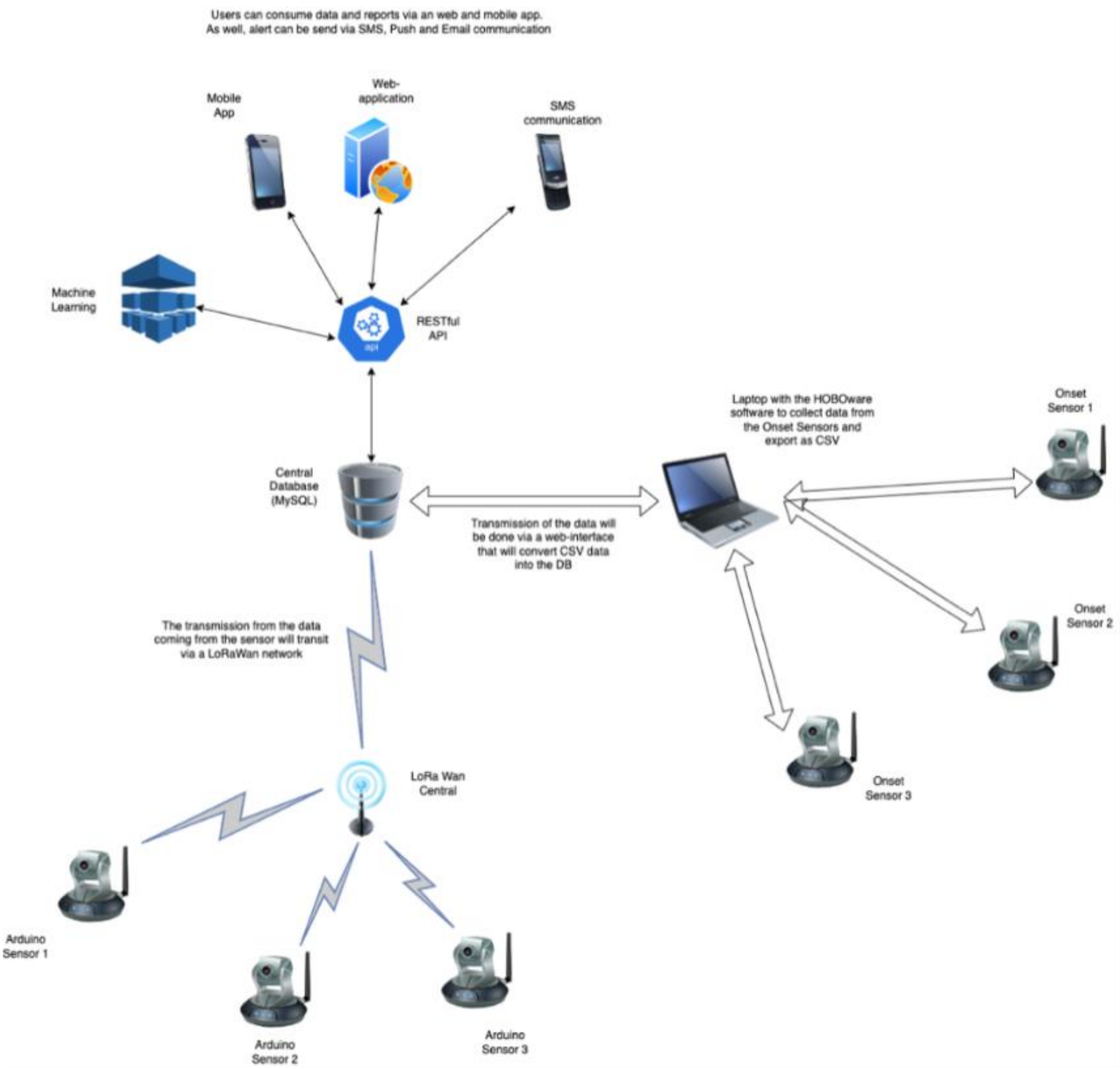
Notes about our visit:

- The water level at the Rontoccocha watershed has increased from 150k to 3 million cubic metres since the cement dam was built.
- The main water user is the agriculture sector.
- Most watersheds drain into other smaller ones.
- There are rural dams and cement dams (built by the local communities and by the government, respectively).
- They recently hired a programmer to help them with the arduino configuration. Arduino are open-source electronic microcontrollers that is used to monitor the level of water (in this case)

During the third day, we held interviews with Rosaura Villafuerte (Responsible for the Governance component at Helvetas) and Augusto Ramirez (Director CEDES) to talk about the challenges the project faces. Our final schedule was:

Day	Activities	Description
Day 1: May 17th	1. Arrival at Abancay during the day 2. Meeting with Marco Sotomayor and other members of the Helvetas team	The first day should function as a better introduction to the Helvetas team. We could probably have better interaction with them in person and talk about the problems, what they think about our proposal.
Day 2: May 18th	1. Leave for the basin head to visit as many sensors as possible 2. Visit EMUSAP headquarters in the high part of the mountain	The second day we would have to leave early to get to the sensors at the top of the mountains. It would be ideal to visit at least one of each sensor and see how the data is collected. We would also visit EMUSAP headquarters and talk to the monitoring team, see how they operate and take notes.
Day 3: May 19th	1. Conduct more interviews	The third day we would discuss more regarding the governance objective. Return to Lima in the afternoon and transcribe our documentation from the field visit.

Annex 2: Solution diagram and collaboration



It is worth highlighting that these solutions work on top of and in collaboration with each other. For this reason, it would be ideal that all the different technological improvements are implemented in unison, in order for the solution to reach its full potential.

In addition to the previous paragraph, whatever technology the program decides to adopt, it must come accompanied by a series of training sessions for the team, and other stakeholders in the zone. This is relevant not only for the proper implementation of the equipment during the life of the project, but also for its sustainability as once the project is over the local population is left with the equipment but without the adequate skills for handling it properly.

Quotes:

[1] “El proceso consiste en ir a recolectar los datos manualmente a donde están instalados los sensores, toma aproximadamente un día” Jan Baiker, technical interview.

[2] “Iniciar el monitoreo eco hidrológico detallado de ellas, para generar a largo plazo importante información y lecciones que se deberían considerar en el futuro, cuando se planifique la construcción de nuevas cochas” (Bosques Andinos, 2021)

[3] “hemos propuesto a la consultora que implemente un sistema de SCADA (Supervisory Control and Data Acquisition) en la parte baja (demanda) y planeamos proponerles para que lo hagan en la parte alta (oferta) también” Danny Saveedra , technical interview

[4] “Cuando viene la lluvia, allí podemos depositar agua y en tiempo de sequía usarlo para regar nuestras chacras, nuestros productos, para regar nuestros pastos y así para mantener nuestros animales.” Oscar Ramos, commoner (Bosques Andinos, 2021)

[5] “Normalmente si un año vienen las lluvias fuertes se espera que el próximo ya no esté tan cargado” Hernán Ibarra, technical interview