UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

CultivAid

Team Possible!

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Table of Contents

Chapter 0: Introduction

Our team
We are group 5 – Team Possible
(Our team's name is "Possible" because everything is possible for us ;))

Members:
- *Nihat Ahmadzada (Leader)(Designer)*
- *Yigit Bezek (Programmer)*
- *Céline Biller (Designer)*
- *Gorkem Çardak (Equipment Manager)*
- *Lasse van Eerden (Presenter)*
- *Samuel Overtoom (Validation Technician)*
- *An Tran Quy An (Programmer)*
- *Wieger Wittrock (Data Programmer)*

The problem we (and the rest of the world) are tackling
The problem we chose is water waste in agriculture.

Motivation for the problem
Water and food are the core of life. Study shows that 70% of usable water goes to agriculture and 40% of this water is actually wasted [24]! Some people already have a water problem, and in the future, without action, study shows that we will have a major water shortage [4].
Also, an increased number of population will require an increased amount of food from the agricultural sector. Even more water will get wasted then, so we need to act fast to prevent water and food shortage.
It is necessary that we find a way to decrease our waste in water, by managing and conserving water in new and better ways. Our solution will help farmers manage their water waste.

Brief explanation of proposed solution
Our solution to water waste in agriculture is to look at the weather forecast, and only use the irrigation system if it is not expected to rain.
We will have moist soil sensors that will tell the Arduino if the soil is dry. Then the Arduino looks at the weather data we gave it. If it is expected to rain, then the Arduino will tell the irrigation system to stop giving the crops water. In this way we will save a lot of water, which will solve the problem of too much water waste in agriculture.

Motivation for the proposed solution
The strength of our solution is the weather data. For almost every location in the world there is cheap and accurate weather data available. This could make our program very effective. We use weather data from Visual Crossing. This data is very accurate and cheap, it will cost you only $0.0073 per year to have accurate weather data [28].

Chapter 1: Literature Review

In this chapter we give a short summary of meaningful publications on the general subject of climate change.

1.
We need to act fast if want to keep the climate target in reach. As seen during the floods in Canada, we are not well prepared enough for worse climate conditions. The flood showed that infrastructure is very important to keep people safe. In Canada the infrastructure needs to be greatly improved before the next (even worse due to increase of water levels) flood. The main conclusion is that poor infrastructures will not hold against deadlier floods, by increase of water levels [1].

2.
Climate change with global warming causes decrease in water levels in The United States' largest reservoir. The water level registered its lowest increases concern in high demand for water sources. According to the article, the first group of people affected by this major water loss are the agricultural communities. Farmers will not be able to use their land like they do now. This, and the water loss, could turn out as great problems in the future [2].

3.
One of the reasons of climate change high carbon release actions are trying to be prevented by reducing emissions rates in US. Major American cities are now working on their own climate plans, as the US government is not trying hard enough. Cities are seen as important places to help reduce climate change. As many cities already have executed carbon-cutting plans, we cannot reduce climate change without working together [3].

4.
The article is about the major loss of coral in reefs and especially in the Great Barrier Reef (GBR). 2258 surveys, held between 1985 and 2012 over a total of 214 reefs, show a total loss of 50.8% of the initial coral cover in the reefs. The main causes for this major loss are crown-of-thorns starfish (COTS) that eat the coral, tropical cyclones, and bleaching of the coral. Due to human activities, the water temperatures are increasing which will lead to more cyclones. Due to human activities (like pollution), water quality is decreasing which will lead to more COTS outbreaks.
To solve the continuing loss of coral cover in the reefs, there needs to be direct action to solve the increasing water acidification and global warming. This will lead to fewer cyclones and COTS outbreaks, and the reefs will be able to recover, as the study shows [4].

5.
Study shows that, due to climate change, the chance of getting a deadly heatwave (as in June 2021 in North America/Canada) is now 150 times more likely. According to climate scientists, the deadly heatwave from June 2021 was virtually impossible without climate change caused by humans. The record-breaking heatwave was considered a “rare event”, but scientists are unsure if the current heatwave models are still accurate enough. The

future remains uncertain until new models are made. Scientists advise people and cities to get more prepared for even deadlier heatwaves [5].

6.
According to scientists, plants will require more water in the future due to climate change. As many people already have water stress right now, this situation will worsen in the future. A study shows that the increasing temperatures and higher levels of carbon oxide will lead to more water consumption by vegetation. This will lower the water levels in rivers and will make it even more difficult for people to get clean and healthy water [6].

7.
Climate change is already actively impacting many regions and there needs to be more efforts for adaption. There is not enough documentation on how adaption to climate change limits the risks and this has to be changed to help decide on further policies. It is also mentioned that most funds are used for reducing emissions and not to finance adaption, while also causing developing countries to becoming indebted and burdened. There is discussion around debt forgiveness and investing in adapting as well as stopping climate change [7].

8.
Large parts of the population in Africa aren't informed enough about climate change, causing many to be unprepared to combat problems caused by it. Climate change literacy is associated with being more likely to contribute towards climate action (adaptation and mitigation). The continent is predicted to suffer of many of the most intense consequences of climate change, making adaptation critical. Climate change literacy rates change dramatically across Africa, especially within subnational areas within countries. Experts advise more intermingling of people from different social standings and spaces as this has been proven to increase knowledge of social and political concepts. This also pertains to climate change literacy [8].

9.
This article mentions how big oil companies, especially focusing on the ones in America, invested many resources in misleading the general public about climate change using advertisement. While internal studies warned of the consequences burning fossil fuels has for the planet, the oil companies chose to ignore various warnings and chose to print ads that denied global warming, claiming there wasn't any proof of it. These companies ran campaigns that influenced the publics opinion and tried to push economic aspects in the foreground. Using fear mongering tactics to manipulate the general public into believing that supporting climate action meant heavily financially burdening them and their families. Nowadays, they present themselves as proactive and "clean" companies, while not acknowledging that using terms like "clean coal" and "low carbon methane" is considered false advertisement. They do not reflect the reality and engage in greenwashing. [9]

10.
The relation between different environments and microplastics is often confused to have no effect on each other, while in reality they relate a lot. In addition to that, too little is known about the transmission of microplastics, even though the bad effects it has on health of humans, animals and our environment is known [10].

11.
Research shows that the islands of the Chesapeake were sinking at approximately 3 feet per 1000 years, though in the 20th century alone the water levels rose 1 foot. The main problem addressed in this article is the rising water level in the world, speeding up the sinking of the Chesapeake islands, which is caused by an increase of carbon dioxide and methane gas release [11].

12.
Meat is responsible for approximately 30% of greenhouse gas emissions, especially beef generally has a much higher carbon footprint than plant-based food. The main environmental problem addressed is the carbon footprint created by the consumption of meat [12].

13.
This paper presents an assessment of the current climate change situation in the G20, as well as recommendations for crucial measures and agreements that G20 countries should take in 2017 and at the upcoming Leaders' Summit (7/8 July 2017 in Hamburg, Germany). CARE underlines the importance of G20 countries taking more action on climate change in order to meet the goals of the Paris Agreement and avoid an unmanageable climatic catastrophe [13].

14.
This article focuses on the factors that cause climate change and its consequences. According to M. Ahmed, usage of primary greenhouse gases (GHG), will play significant role in the global warming problem. This will lead to: extreme heat, change of plant phenology (for worse) and an increase of vector borne disease. [14]

15.
The focus of this paper is that mental health will be impacted by climate change. Extensive research has connected exposure to extreme weather events associated to climate change to harmful consequences on physical health, mental health, and social relations [15].

16.
Agriculture and food security are predicted to be significantly impacted by climate change, though the impact will vary by region and by crop. Combined with the increasing global population, there is an urgent need for agriculture to adapt to ensure future food security for this growing population. Adaptation strategies include changing land and cropping practices, the development of improved crop varieties and changing food consumption and waste. Recent advances in genomics and agronomy can help alleviate some of the impacts of climate change on food production; however, given the timeframe for crop improvement,

significant investment is required to realize these changes. Ultimately, there is a limit as to how far agriculture can adapt to the changing climate, and a political will to reduce the impact of the burning of fossil fuels on the global climate is essential for long term food security [16].

17.
The rapid development of plastic industrials has created a variety of plastic products, causing revolutionary progress in chemistry, physics, biology, and medicine. Large-scale production and applications of plastics increase their possibility of entering the environment. Previous environmental impact studies typically focused on toxicity, behavior and fate; limited attention was paid t greenhouse gas emissions and climate change. With the increase of plastic waste, the threat of plastic pollution to the earth’s climate has been gradually increasing [17].

18.
It is no doubt that the roots source of climate change is overpopulation. But then, what is cause the population on our planet to increase dramatically recently? And what are the other effects of population over-growth to our society? How could we deal with such a complicated situation as this? Many questions are not yet answered [18].

19.
Researchers conducted an observational study of the Arctic’s thickest ice in the north of Ellesmere Island and Greenland. They documented the evolution and dynamics responsible for the polynya. They argued that strong divergent winds associated with an intense and long-lived Arctic anti-cyclone contributed to the development of the polynya [19].

20.
Water is the most precious and limited resource that is needed for the existence of humanity. However, The World Health Organization (WHO) has reported that more than 40 percent of the global water-stressed population lives in Sub-Saharan Africa. In this region, only an estimated 44 percent of the urban population and 24 percent of the rural population have adequate sanitation. People will have to obtain water from streams and ponds that often hold disease-causing organisms, such as those that cause cholera, typhoid fever, and infant diarrhea [20].

21.
Heating of the temperature causes problems such as an increase in temperature in seas and oceans which is not needed for some animals that live there. Because of that, some animals are even going to become extinct. Such as Albatrosses which divorce because of bad living conditions [21].

22.
In Vancouver, rain and winds which caused flooding, destroyed many people's houses, farms and even a whole town. Roads also disappeared and were destroyed because flooding washed out some bridges and everything filled up with water [22].

23.

Because of climate change, the temperature rose, which melted ice and it caused to increase in the level of water in seas and oceans, which caused floods, and this flood destroyed everything including agriculture, energy and transport production. Because of the raised temperature forests burn because of overheating. In some places, temperature rise causes to evaporation of seas and oceans which creates the death of sea animals [23].

Chapter 2: Identification of General Problems and Challenges

In this chapter we identify 11 general **problems & challenges** from the list of publications in Chapter 1

- Due to human activity, the temperature on earth keeps rising. This will cause many different problems in the future. One of them is the **increasing number of tropical cyclones** since the water temperature will also rise. Tropical cyclones will deal a great impact on our environment. Until now these cyclones are already the main reason (46%) that we lost 50.8% of the initial coral cover in a period of 27 years [4]. In the future, with increasing temperatures, we will **lose even more coral** and all the animals living in the reefs.
- Another problem we will face in the future, due to climate change, is the increasing amount of **deadly heatwaves**. This year there were record-breaking heat waves in North America and Canada. The existing models about heatwaves we have now, will not warn us about deadly heatwaves for a very long time anymore, according to scientists [5].
- There will also be **water problems** when the temperatures keep rising. Due to more carbon oxide in the air, vegetation will consume more water in the future. This will **lower the water level in rivers** and will make it **more difficult for people to get clean and healthy water** [6].
- Agriculture and food security are predicted to be significantly impacted by climate change, though the impact will vary by region and by crop. Combined with the increasing global population, there is an urgent need for agriculture to adapt to **ensure future food** security for this growing population. This is possible to an extent but not limitless, there will be a point where we can't adapt anymore to keep up with the climate change [16].
- Developing in new era industries **increasing release of carbon** which is drastically affecting climate change to a negative feedback loop [1].
- With the rapid increase in temperature, a huge amount of **ice of polynya in the Arctics and South Pole starts to melt and decrease over the years**. This not only **increases the sea level** but also **changes the habitat and the environment of animals**. The problem should be addressed so that we can maintain the living conditions of those animals [19].
- Additionally, the **lack of research and documentation about climate change** poses various problems. As study shows, many people are not well enough informed about the dangers of climate change to tackle these dangers (adaptation). More documentation also leads to more action against climate change, which we are missing at the moment. Many areas are already seriously impacted by climate change which renders mitigation as unhelpful. The living conditions of large amounts of people could be greatly improved if more focus would be put on adaption, by documenting more about climate change there where needed, as solely preventing climate change is not feasible [8].
- According to M. Ahmed**, usage of primary greenhouse gases (GHG)**, will play significant role in the global warming problem because of this heat will be extreme,

change of plant phenology (for worse, as the first flowering days of different flowers will have a great difference in the future. Which will not support our existing environment [24]) and an increase of vector borne diseases [14].

- According to S, Clayton, there is a huge possibility that the world will suffer from Global Warming if we **don't find a balance between individual's mental health and social responsibilities** [15].
- According to Schramek, C. and Harmeling, S., **if G20 countries do not commit** for protection of the poor and vulnerable countries from climate change, it will speed up the consequences of climate change significantly [13].
- **Greenwashing** is widely used and there is a lack in educating the public about it. Many companies use greenwashing to appear “clean“ and ethical, while still harming the environment. Examples of this are big oil companies trying to depict fossil fuels such as methane as unproblematic and fast fashion brands selling “green“ clothing lines. This is done to deceive customers since there is **no legal definition for** buzzwords like **“organic“** and **“environmentally friendly“** [9].

Chapter 3: Identification of Relevant Problems

In this chapter we identify 6 problems we find relevant, urgent and interesting, not yet been addressed effectively

Problem 1 – **Flooding** leads to an increase in the level of water on the ground and in the sea and ocean. This will cause a lot of damage to agriculture, residence and transportation. In scientists opinion, flooding is one of the main problems caused by climate change which needs to be prevented. This is because a lot of peoples/animals home will be under water in the future without action [22].

Problem 2 – **The combination of climate change and a continuously growing population** causes food insecurity. Climate change will make certain area's unable to produce food the way it used to or at all. This will decrease the overall food production in the world and with a growing population, it will cause a food shortage in the future [16].

Problem 3 – Not doing enough research and putting enough resources into the adaption of climate change, but instead focusing on mitigation. Many suffer from the effects of climate change already and several communities are especially vulnerable to it, even if they're contributing minimally to climate change themselves, i.e., Indigenous communities [8]. There also is a lack of literacy on climate change. There are specific problems that are well known, i.e., overheating of the planet. However, issues like greenwashing and how advertisements manipulate and deceive the public aren't widely understood. Which could make these issues more dangerous [9].

Problem 4 – Noise pollution. In developing countries, people construct roads and highways through mountains and forests. This causes noise pollution to the habitat of nearby animals and residents. Noise pollution affects the behaviors and living habits of both animals and humans, for example: psychological disorders, animals migrate, … This small change to the environment can have a huge contribution to the overall climate change. Although there are some solutions for these problems, the materials are expensive and not applicable for such overcrowded and developing countries. This can lead to a great problem in the future [26].

Problem 5 - The effect of global climate change on mental health. Global climate change has both direct (change of temperature and weather) and indirect (economic loss, forced to migrate / collective violence) effects on mental health. The most common impacts are anxiety and post-traumatic stress. Residents and especially children are vulnerable to losing their home and their future [15].

Problem 6 – Water waste in agriculture. At the moment, there are already many people that have a problem finding healthy and enough water. This problem will get even worse, as study shows that in the future we will have a major water shortage [4].
The most water waste happens in the agricultural sector, which is also one of the most important sectors (as food is very important). 70% of the water in the world is used for agriculture, and 40% of this water is wasted! We need to find a solution for this fast [24].

Chapter 4: Problem Selection and Motivation

We chose the problem: **Water waste in agriculture.**

Currently there are already too many people struggling finding (healthy) water. Study shows that, we will have an even bigger water problem in the future, based on the current amount of (healthy) water being wasted [4].
The two most necessary aspects of life are water and food. Climate change has a direct impact on water shortage which, according to studies, agriculture is the sector that is the most affected by water shortage [2]. In the future, without action, there will be a water and food shortage. This could be seen as one of the worst possible outcomes of the climate change. That is why water waste in the agricultural sector is the most important problem, that needs to be solved.
To tackle this problem we looked at the place where water is wasted the most: the agricultural sector.

Because water is wasted on such high scale, it is a really interesting topic to make solutions for. Even though a problem should be tackled by its roots, we need to solve the problem directly for the people that cannot wait until the water sources are clean again.

Why is this problem relevant and urgent?
As we already said, water is the core of life. Study shows that 70% of water is used on agriculture and 40% of this water is wasted. An increased number of populations will require an increased amount of food from the agricultural sector. Even more water will get wasted then, so we need to act fast so there won't be a water and food shortage.

But we already are in a water crisis. We are facing water shortages and opposite with droughts or floods. Almost all countries experience water shortage every year. Research showed that, unless the water use/waste is drastically reduced, shortage will affect the entire planet by 2040 [25].
Note that less water use will not be a solution for the water waste, it only delays the water shortage.

Why is this problem interesting?
Agricultural production consumes more fresh water than any other human activity. Many developments can be made to improve sustainable agriculture systems. It is our task to find these good solutions.

Chapter 5: Potential Solutions

In this chapter we explain 7 potential solutions to our problem, water waste in agriculture.

1. **Droplet irrigation system**

Explanation
Drip irrigation or trickle irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface.

Advantage, benefit
It prevents diseases by minimizing water contact with the leaves, stems, and fruit of plants. It also allows the rows between plants to remain dry, improving access and reducing weed growth. Finally, it saves time, money, and water because the system is so efficient.

Disadvantage, Downsides
The installation process needs time. Sometimes it may need court approval in some countries. Sun heat affects tubes, they can get broken for excessive heat production. Plastic tubes affect soils fertility. Sun degrades plastic sometimes and that affect soil and fertilizers too.
Tubes get clogged sometimes. Water cannot pass through, and roots get dehydrated.
If droplet irrigation is not installed properly, then it is a waste of time, water and money.

2. **Watering system (scheduling irrigation) with the weather forecast in mind.**

Explanation
Check the weather forecast and tell the irrigation system to handle accordingly. Look at for example, high or low temperatures and rainy or dry days that can affect the irrigation amount for crops.

Advantage, benefit
Weather monitoring can help cut costs, produce higher crop yields, and prevent over or underwatering. Also, sensors allow farmers to make better decisions about pesticides, watering, and preventing disease. It is also easy to implement as there is a public weather forecast available for almost every place on earth.
You can anticipate on:

- Rainfall: see how much rain has fallen during a set period
- Temperature: track temperature changes over a day, week, month, or longer
- Humidity: see if the air is very dry and the plants might need more water

Disadvantage, Downsides
The water irrigation system might not be optimal, if the weather forecast isn't either. It depends on the forecast.

3. Weight the animals and give them water according to their weight

Explanation
Quite amount of water is spent on animal husbandry. To prevent that, we can use smart water feeders like a hamster's water feeder with a camera. This makes it possible to identify all animals and then calculate for each of them how much water they need per day, according to their weights. Then we simply give that amount of water daily and not more.

Advantage, benefit
It would save water, as all the animals will get the optimal amount of water.

Disadvantage, Downsides
If the sensors and cameras fail it may be lethal for the animals. It is also very difficult to know how much water an animal needs.

4. A field of sensors (pressure & moisture) under the crops, to know which part of the field needs more/less water.

Explanation
Underground sensors that see the fullness of soil on water and humidity so that each meter is managed properly and all of the farmland is equally irrigated with the required amount of water.

Advantage, benefit
the chance of survival of crops is increased, so less water waste. For example: drought, local ground flood and overall watering system in farms are managed well. Each plant gets enough water. Increasing the soil quality will also increases the quality of crops.

Disadvantage, Downsides
System might be complex and expensive on large scale. Also, when some of the sensors break, it might be hard noticing and repairing on a large scale.

5. Only using very high quality, nutrient rich, soil and water

Explanation
By using the best soil and water there is, the plants will grow better and there will be a smaller change of the crops dying. This will decreases water waste.

Advantage, benefit
It will decrease water waste, as way more plants will survive. The crops will grow faster, and there will be less insecurity about a potential harvest in the future.

Disadvantage, Downsides
Limited range of crops can be utilized, and it is very expensive.

6. Using more improved greenhouses

Explanation
A Greenhouse is an enclosed space of a garden that is designed to be the optimal living space of crops. It will for example magnify the light of the sun, and protecting plants from freezing. It creates a small ecosystem from which most factors are under control.

Advantage, benefit
The crops health and survival chance is greatly increased. You also need less pesticides, water and fertilizers. There is a higher return per unit area than crops that are grown in the open field. You are now also able to produce food throughout the whole year

Disadvantage, Downsides
The lack of pollination by bees. It is very expensive to operate. It requires lot of energy, and especially in extreme weather conditions it is difficult to manage.

7. Hydroponics

Explanation
Hydroponics is a way of farming crops. Instead of using soil for the plants to grow in, you only use water. This may sound impossible but it works really well. All of the water is full of nutrients and it is being held in a big container, with the plants roots hanging in the nutrient-full water [27].

Advantage, benefit
Since all the water is in a big container, there is almost no waste. Study shows that hydroponic farming uses only 10% of the water used for “normal” crops farming. And the crops hanging in water also grow 50% faster! Also you don’t need as much human interaction if the hydroponic farming is done in a secured greenhouse.

Disadvantage, Downsides
The main disadvantage is that is very expensive to manage a big hydroponic farming installation. Also it only allows smaller plants (that can actually grow in water). You also need a higher level of education to operate in these hydroponics green houses.

Chapter 6: Solution Selection

In this chapter we will talk about our chosen solution to the problem of water waste in agriculture. **Our solution is making a system that anticipates on the upcoming weather, and tells the irrigation system.**

The final program should be able to read the weather forecast and tell the irrigation system to handle accordingly. It will look at high or low temperatures and rainy or dry days that can affect the irrigation amount for crops.

If we manage to make a program that can read the weather forecast, and then "tell" the irrigation system to give the plants more/less water, then the water waste problem in agriculture will have a great step towards being completely solved.

The power of this solution lies in the fact that almost everywhere in the world, there is a free and public weather forecast for that specific place. This will mean that our program could be used all around the world, making it a very effective solution.

The biggest risk of this solution is of course that a weather forecast can differ from the actual weather. We don't think that this is big problem because:

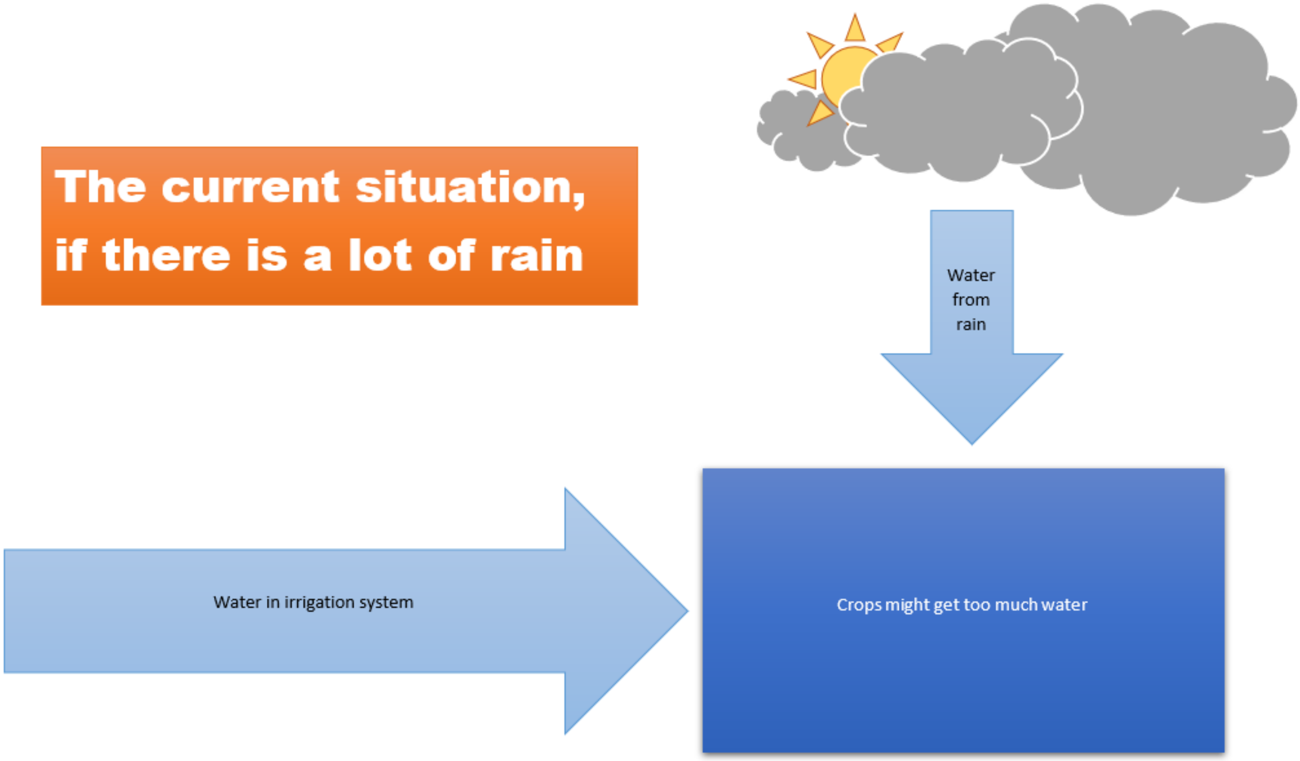
- In the future there will be all new technologies that can predict the weather forecast very accurate. We expect that research into predicting the weather will also get a great boost, if it shows that our program will actually reduce water waste.
- We can tackle the problem of a miscalculated weather forecast by adding sensors (like humidity and temperature) around the farm to be certain of the actual weather. We can then check if the forecasted weather is the same as the actual one. If it is not, then we can make changes to the irrigation system (that is functioning on wrong data), so no crops are lost.
  These sensors could be on the program if it is near the farm, otherwise it could be connected to the program in another way.

We can validate our solution by for example using our program on a very small scale (as we don't have an irrigation system). We could grow two carrots outside, one of them is given water like usual, and the other one is given water anticipating on the weather forecast. If this shows that we will save water, without greatly decreasing the quality of the carrot, then our program is validated.

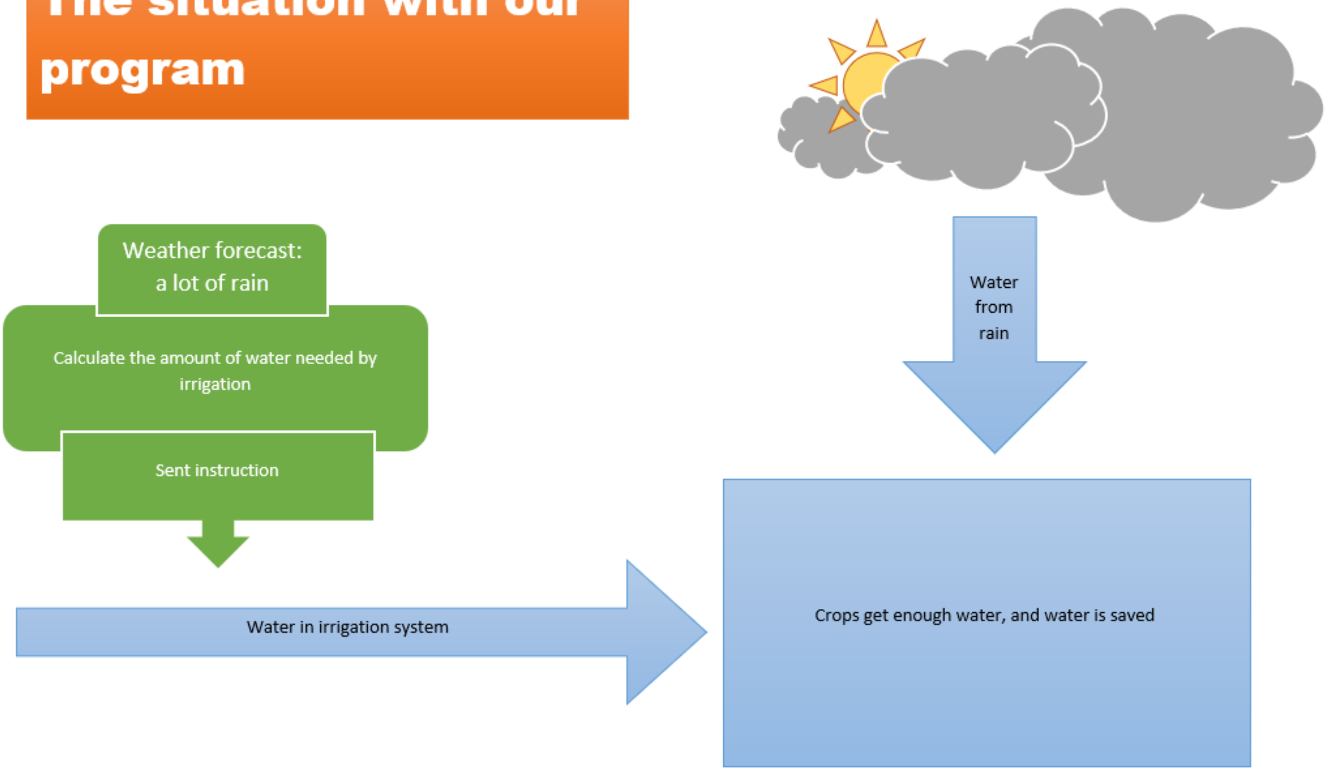
This solution is better than the other ones, because this solution will work all around the world, making it very effective. Also it will not be very expensive to set up in large scale farming (like an improved green house, hydroponics and expensive soil) as the data of weather forecasts are free and made for almost everywhere in the world.

This is how our program could operate for (expected) very rainy days:

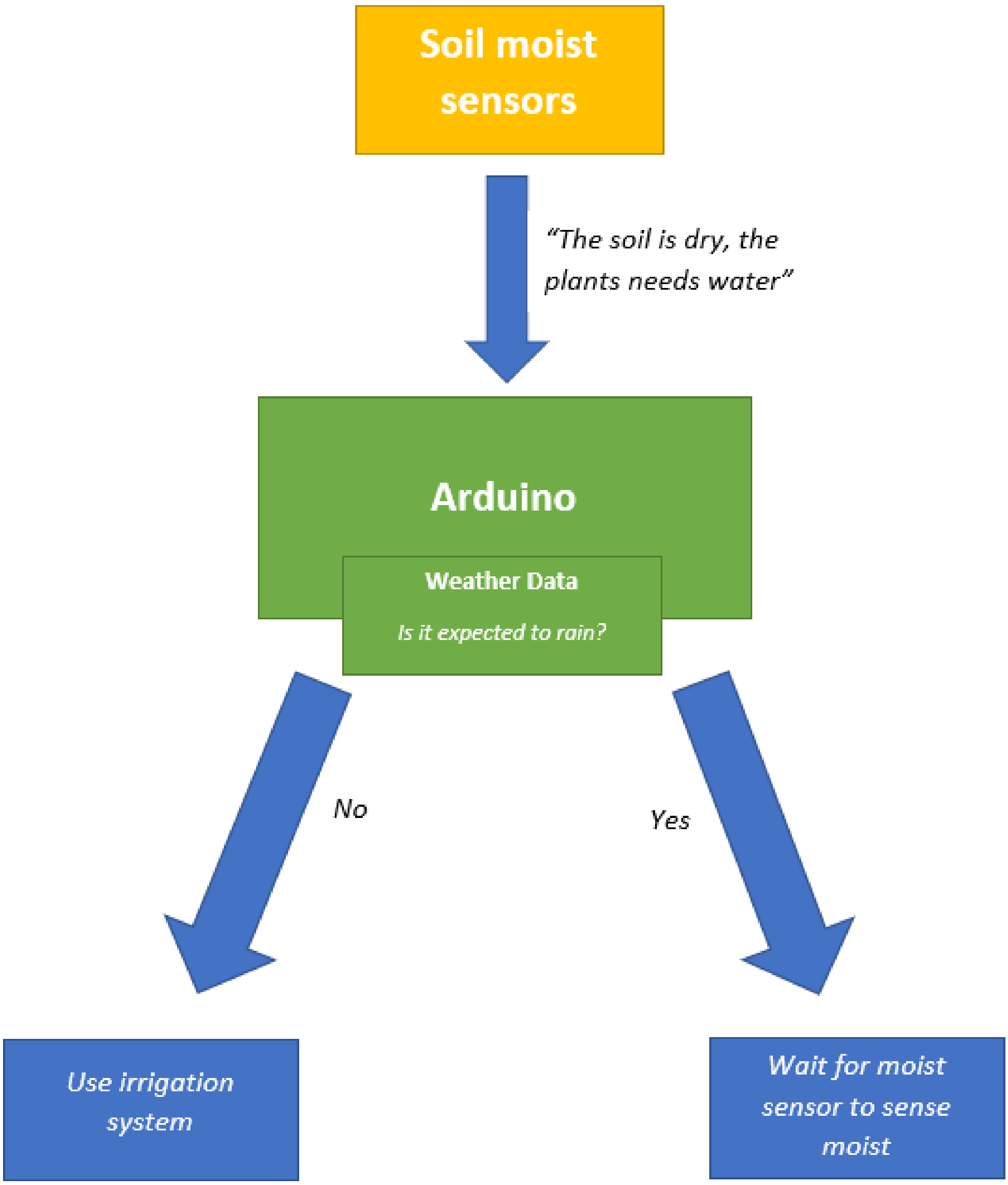
The current situation, if there is a lot of rain



The situation with our program



After getting feedback, we made changes on how our program will work. Instead of first looking at the weather forecast, we will now look at the soil first. If the soil of the crop is dry, it needs water. Then we will look at how we are going to give it water: is it going to rain, or do we give the water ourself by irrigation. So this is how our program will look now:



Chapter 7: Methodology

In this chapter we describe our methodology (guidelines) for our project. We also give everyone a role in the project.

First, we give a modular approach of the project:

Name	Modules	
Nihat Ahmadzada	Team leading	Designing/building product look
Yigit Bezek	Programming	Validation
Céline Biller	Data analysis	Designing/building product look
Gorkem Çardak	Equipment Manager	Programming
Lasse van Eerden	Presentations	Data analysis
Samuel Overtoom	Validation	Equipment manager
An Tran Quy An	Programming	Data collection
Wieger Wittrock	Writing Document, Data collection/programming	Designing product work

- **Team leading,** helping the team work together. Merging the modules.
- **Presentations,** making and giving presentations.
- **Equipment manager,** making sure the equipment (sensors to 3d-printed cases) is managed. Checking if the sensors need calibration.
- **Programming**, using Arduino for calculating humidity and moisture from the sensor. Using the data online from the weather forecast to predict and maintain the water irrigation system. Designing the UI system (information) on processing. **(Programming Data,** focused on implementing/validating the weather data)
- **Data analysis,** find the best data from the best weather forecast and find out how reliable the forecast data is.
- **Data collection and usage,** collecting all the data we need from the weather forecasts and make them readable for the Arduino.
- **Designing product work,** designing the circuit and other images that help explain our work (like the one above with clouds)
- **Designing/building product look**, designing the look of our case/program. Look into using the 3d-printers or what other material. After the design is done, it should be built. For example using the 3d-printer for the designed case for the Arduino. Look into using the 3d-printers or what other materials we could use.
- **Validation,** testing the prototype, and measuring the results. Then write about it.
- **Writing Document**, making sure the text about everything we did in this document is clear to understand, and add information if it is not. Making sure the document looks good and that all the resources are also well documented.

Samuel and Gorkem, were also in charge of ordering equipment.

The equipment we need for our prototype:

- Arduino Uno
- Power supply
    - for our prototype validation this just could be our laptop
- Prototyping board
    - for generalization of the circuit
- LEDs to display if it is expected to rain
    - so the user can see the data.
- Insulated Jumper-type cables
    - to connect the sensors to the Arduino.
- Soil-moisture sensor
    - to measure relative moisture data in the soil.
- Dht11/Dht22
    - to measure relative humidity and temperature in the air.
- 3D printed custom casing with sensor holes.
    - so the Arduino is protected.
- Cheap accurate weather data.

This was for our basic scenario, for the ambitious scenario we also need:

- LCD
    - to display the temperature outside.
- Temperature prob
    - to measure relative temperature data.
- RGB LED
    - to display humidity.
- User interface made in processing
    - so the user gets to see more information.
- Ethernet shield for the Arduino
    - to upload weather data wireless to the processing interface.
- Data for many crops
    - the perfect amount of water they need and ideal temperature, so we could use multiple crops for our prototype.

Data analysis:

For data analysis there are many sources to choose from. The one we chose is Visual Crossing [28]. It has a lot of data for many different aspects of the weather (e.g. temperature to visibility to humidity).
We are going to use the weather data for Enschede. This data comes from actual weather stations in the Netherlands, for example the one in Hengelo. Next to that, a seven-day forecast can accurately predict the weather about 80% of the time and a five-day forecast can accurately predict the weather approximately 90% of the time. However, a 10-day or longer forecast is only right about half the time. This does mean that we should refresh our forecast at least once in 3-5 days to get the most accurate data.

Of course, you could also incorporate data from many different sources which would increase its accuracy but we chose to keep it to Virtual Crossing for now as to not make it too complicated yet. But also it will not make a real difference if the same weather stations are used. Only if Virtual Crossing is *missing* a weather station, that a local weather forecast *does* use, we will have a lower accuracy. Combining weather forecasts could always be introduced in a later stadium, as part of our ambitious scenario.
But there are no signs that Visual Crossing is missing weather stations, so the data should be very accurate.

Data collection:

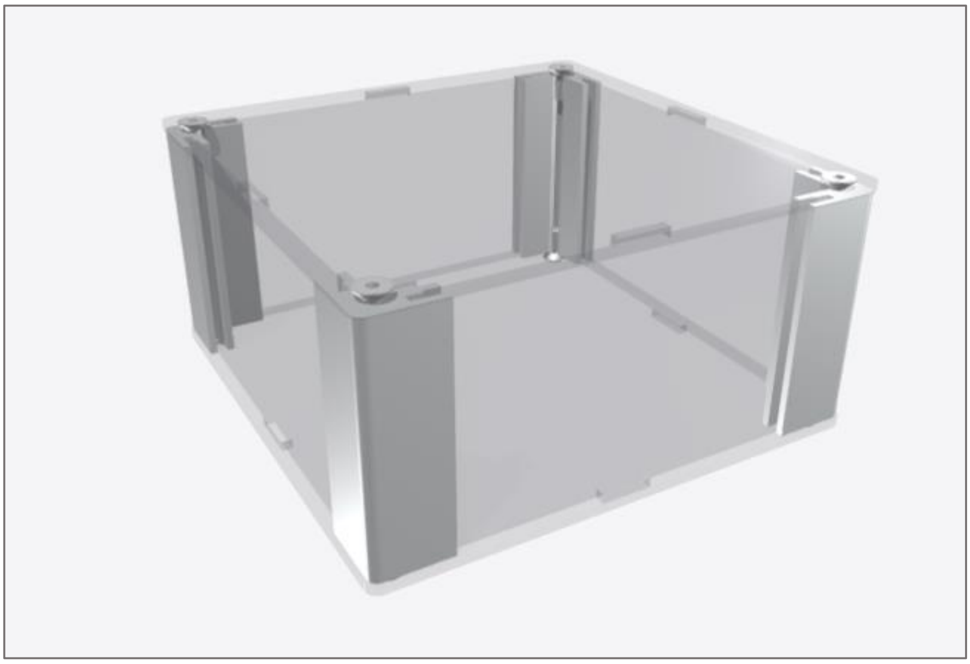
As we discussed in our solution explanation. Weather forecast data is not expensive. You can download a 15-day accurate (for the first 3 days most accurate, as explained above) weather forecast for almost every location for only $0.0001. So you will spend $0.00122 per year to have accurate weather data [28].

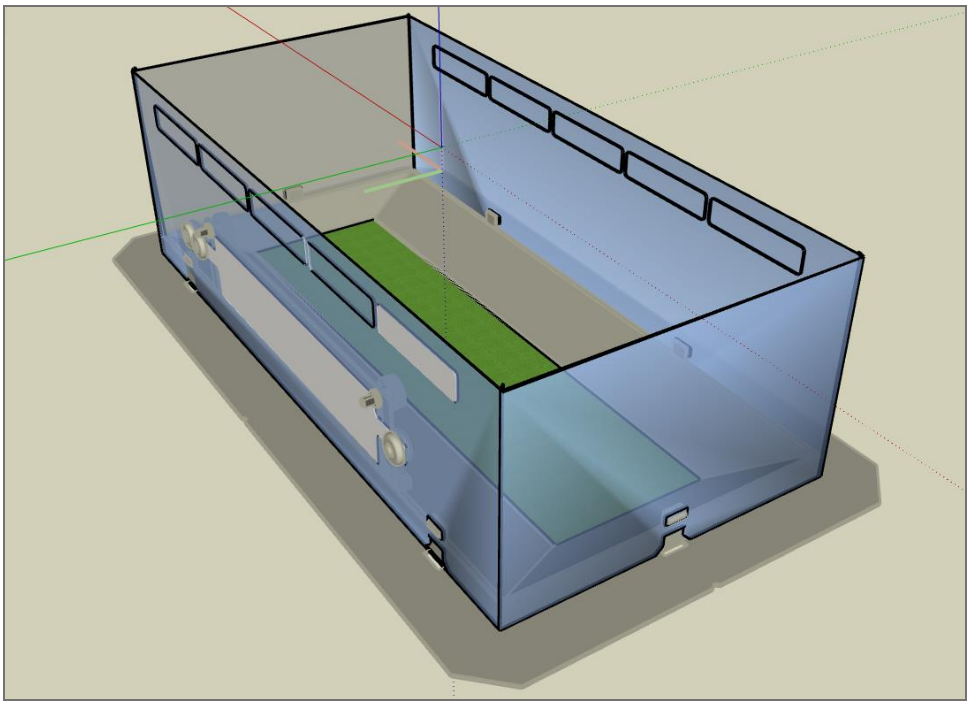
Since this cheap data is one of our strongest points of our solution, we have to make sure the Arduino can do something with the data.
Luckily, we can download weather forecast data in many forms: CSV, Excel or JSON. But which is the best to send to the Arduino?
While Excel is the easiest to read for humans, it is not the best data form to use for our program. Instead JSON will be the best choice, as there is a library in Arduino that focuses on the conversion between JSON data, to variables in Arduino [28] [Appendix A].

This concludes our data analysis and collection, we can now use the data from accurate weather forecast in our program. We can now code it so our program will tell the irrigation system if it is expected to rain and it will turn a LED on for the user. We could also use the humidity value to give a RGB LED a value ranging from green (100) to red (0).
Finally, for our ambitious scenario we could make the Arduino sense the temperature and display it on a LCD or Processing sketch.

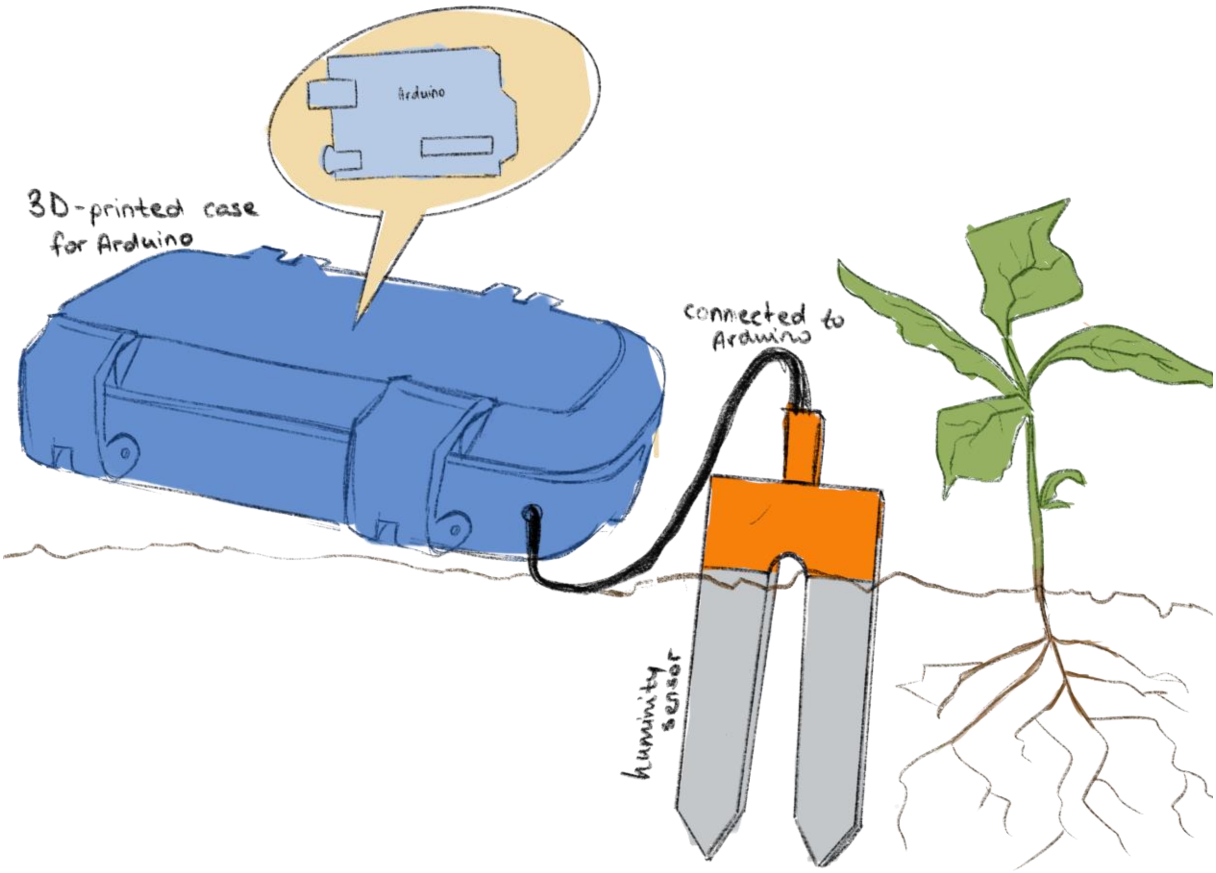
Our product look (casing):

Since the Arduino could be outside, we are planning to print a 3d case for our model. The case will be made of reusable materials. We are making a case for protecting our model from external risks, such as accidental hits, fire or water. These are our first designs for the casing:





This is how our prototype could look like:



The Arduino in the case is connected to the humidity (soil moist) sensor, which is placed close to the plants. There is also the possibility of connecting multiple sensors to one Arduino.

For our ambitious scenario, the Arduino would have a wireless connection to communicate the humidity in real time. But for our prototype it, we can put the Arduino next to the crops as this can validate our program.
Other ways to communicate from the Arduino inside, to the sensors outside would be connecting the Arduino to the irrigation system mechanic, if the farm has this mechanic.

Programming:

For programming, we will use Arduino for collecting the data and connecting the functionality of other components. For our ambitious scenario, we will also use Processing for user interaction and to give the user more information.
To communicate with Processing, we will have to import the "processing.serial*" library so the user can interact with the program through the Processing interface, and possibly also libraries for the sensors.

Another ambitious scenario would be if the user could choose what kind of plant he wants to grow, and the program will then import the library data of that plant. The library consists of the ideal environment for the plant to grow such as level of soil humidity, moisture and temperature.
For our prototype, we will not use this data, as we will only grow one type of plant.

What our prototype will do however, it will take the data from the ArduinoJson weather data, as mentioned above. When the soil sensor tells the Arduino that the plant needs water, the Arduino knows if it will rain and makes a decision based on this information. If it will rain, the Arduino will tell the irrigation system to then reduce the amount of water by lowering the pump power.

Sensors also read the data from the humidity for calculating the time for irrigation systems to start. It is recommended to water plants in the early morning or when the moisture or humidity is full because it will reduce the amount of water, dissolve the frost in the bed and allow the soil to dry out better.
Our program is going to calculate the amount of water needed for the plant within the given parameters of external conditions (the data from the weather forecast, temperature, humidity, moisture level of the soil, and the cast intake). It will consider all these parameters and water it daily with the bare required amount of water. Which will prevent water waste as its natural outcome.

Chapter 8: Validation

To validate our project as a working product in the physical world, we will have to run a set of tests on our product. To verify that the tests are viable, we will run the same set of tests on a piece of land or various areas of soil outside of our product.
The first test would be the quality of the equipment; do the sensors work? Is the basket/flowerpot leaking? Is the soil the same quality as the soil for its use? Is the Arduino using the right weather data?
Once we have the start values for each part of our equipment, we will have to run a test to check if the plants all grow equally fast, for this project the only difference should be the regulation of getting water of the plants. For the first week of growing the seeds we must choose the plants that are growing equally fast and test the difference of water regulation on those plants to prevent false results.

In the next couple of weeks, we must grow both the regulated plants and the unregulated plants in the same room[1], at the same temperature with the same amount of sunlight, preferably in the same corner of the room.
Lastly (and most importantly) during every phase and while the entire project lasts, we will have to check the amount of water used for growing the crops.
To check this, we will measure how much water we (as the irrigation system) give to the crops.
If the crop, that is connected to our program, uses less water from irrigation than the "normal" crop, our validation is successful.

When testing we found out that the sensors are perfectly working and there were no physical problems, like a leaking basket. We grew two basil plants for two weeks. They had the same growing condition, and the only difference was in the amount of water they got.
The two weeks have not been the best two weeks to test out a system designed such as ours, it was dry most of the time.
We tested our system on the two Basil plants between the 14th and the 27th of January, based on weather data provided by Visual Crossing, the forecasted weather is displayed below.

14	15	16	17	18	19	20	21	22	23	24	25	26	27
dry	dry	dry	dry	dry	drizzle	drizzle	dry	dry	dry	dry	dry	dry	rain

One plant got regulated water, twice a week half a cup. The other plant did not get any water unless for three days ahead there was no rain expected. The first week was almost entirely dry and the little amount of rain was not enough for the plant to survive, so we (as the irrigation system) still used almost the same water amount as for the "normal" plant.
The second week had 1 day of rain, near the end of the week, which saved a quarter of a cup of water. Both plants grew just as fast, and all other conditions were the same.

1. Since we have to do the validation during the winter, growing plants outside could be a challenge. We can grow them inside and when it is raining we give them "extra" water.

As you might guess, we could not prove that our regulated plant used a lot less water than a plant in likewise conditions would. Still, we did save a bit of water, which confirms that our system will save water, but more in times when there is more rain expected.

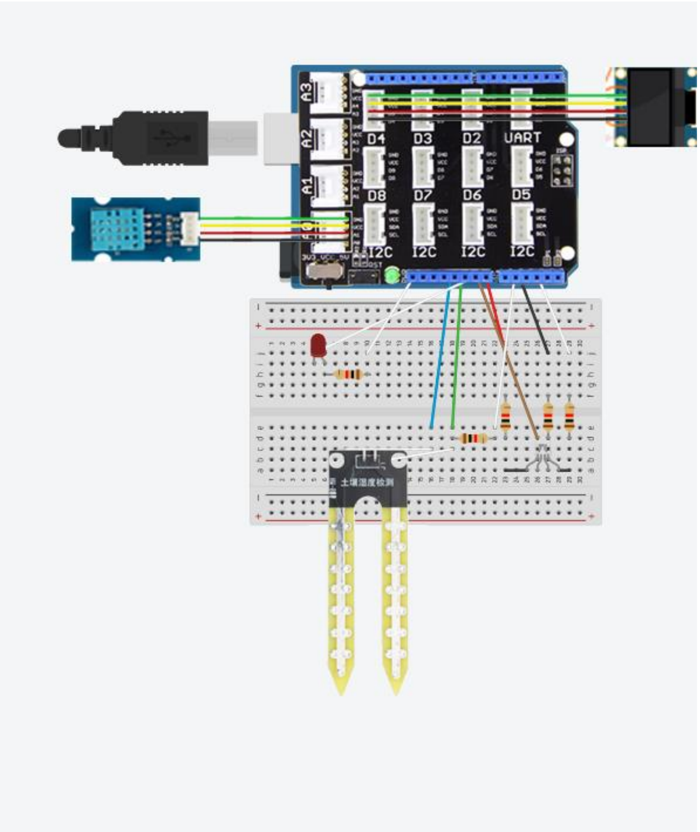
Luckily we did another validation to get actual values on the amount of water we saved when there was more rain expected. This time we only looked at one week. We had two lettuce plants that needed water every day. The plants had the same growing conditions, except for the fact that one of the plants was given water traditionally, and the other plant was given water by anticipating on the weather forecast of Visual Crossing.
This time there luckily was a bit more rain, so we could now see noticeable differences in water usage between the plants.

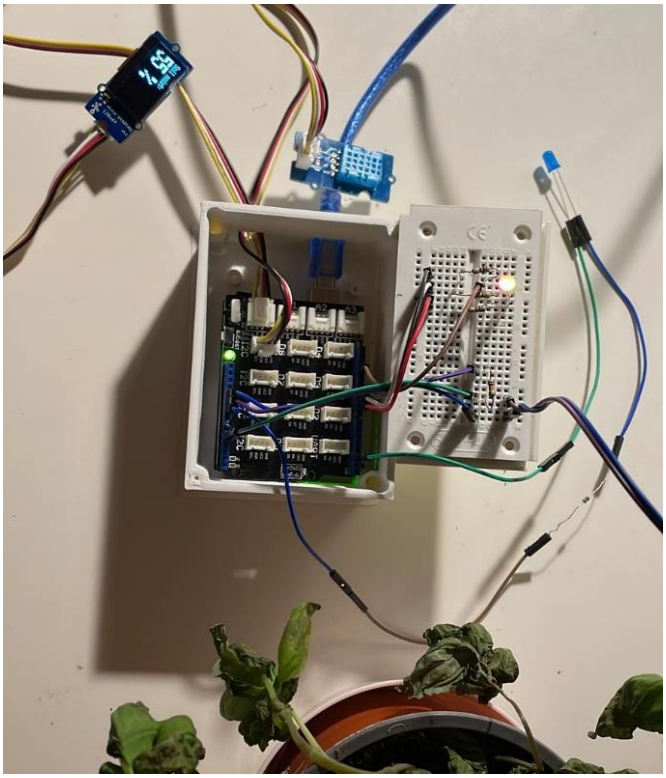
	Expected and actual weather	CultivAid plant	Traditional plant
14-1-2022	Dry	Irrigation: 50ml Rain: 0ml	Irrigation: 50ml
15-1-2022	Dry	Irrigation: 50ml Rain: 0ml	Irrigation: 50ml
16-1-2022	Slightly raining	Irrigation: 43ml Rain: 7ml	Irrigation: 50ml
17-1-2022	Full rain	Irrigation: 22ml Rain: 19ml	Irrigation: 50ml
18-1-2022	Raining	Irrigation: 39ml Rain: 7ml	Irrigation: 50ml
19-1-2022	Slightly raining	Irrigation: 43ml Rain: 4ml	Irrigation: 50ml
20-1-2022	Almost dry	Irrigation: 48ml Rain: 2ml	Irrigation: 50ml
21-1-2022	Slightly raining	Irrigation: 45ml Rain: 5ml	Irrigation: 50ml

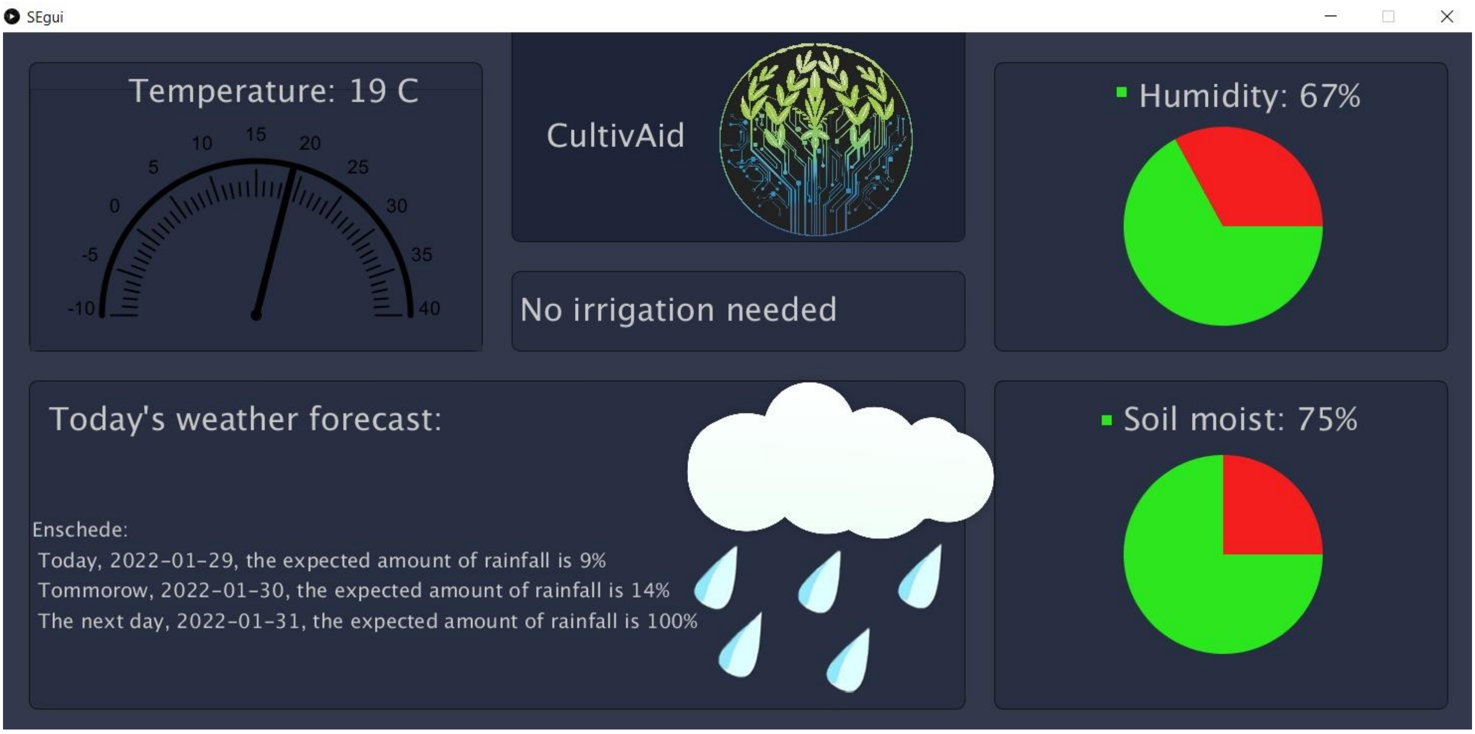
As you can see, this week there was more rain so in theory our program will save more water, and so reduce water waste in agriculture.
Both plants had the same growth, and there were no differences in growing conditions except for water.
The traditional plant was giving a fixed amount of water everyday of 50ml, while the CultivAid plant was given irrigation water based on the expected (which was the actual) weather. In total, the traditional plant was given 400ml by irrigation and the CultivAid plant was given 384ml, 340ml from irrigation and 44ml from rain.
This means we saved 44ml of water in one week, that is almost 13%.

This is actually pretty good, as our program can be used almost everywhere in the world and at all times. But we have to remember that 13% is only for when there is a lot of rain.
We now validated our program on basil and lettuce, but it would improve our program if we also looked at other sorts of crops. Also, we tested our program on small scale, a better test would be to connect it to a farmers irrigation system and look at the results.

Chapter 9: Results and Conclusion







We made a program that senses temperature, humidity, soil moisture and takes into account the weather forecast. The program consists of:

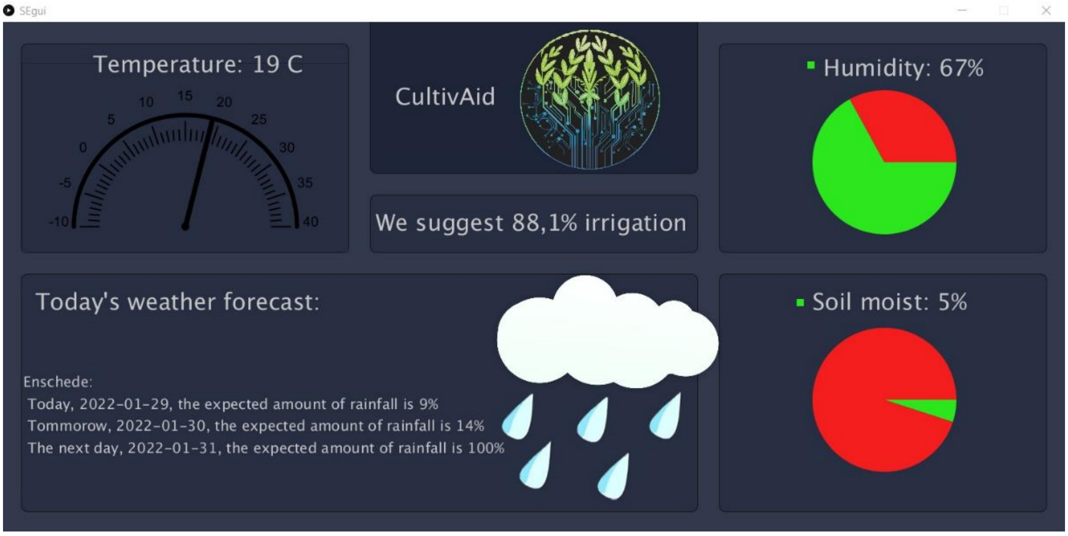
- temperature and humidity sensor
- soil moist sensor
- OLED display
- LED to indicate rain
- RGB LED that changes from green(100%) to red(0%) according to the sensed humidity
- Arduino Base shield
- 3d-printed protective case
- A processing interface that shows multiple data and suggest an irrigation level

As you can see we successfully implemented multiple things from our ambitious scenario, like the RGB LED, OLED display and a complete processing interface. We also decided to use a live API, instead of the ArduinoJson library [Appendix A], as we would run out of memory space if we would have connected all the sensors together with the library. An advantage of the live data API from Visual Crossing is that the data will be continuously changed, so the accuracy is at its highest. A downside of a live API from is that your computer (Processing) needs to be connected to the internet at all times. This downside is not really a problem as the computer is always inside.

For the processing interface we made it display many values that could help the farmer manage its water waste. We calibrated our sensors and found values we could use for the program. The optimal value for the humidity sensor for plants to grow is between 50% and 60%, while the optimal temperature for our plants to grow is 25 degrees Celsius. If the soil moist sensor senses a value below 40%, the plant needs water.
We then look at the expected rainfall and make a calculation taking the optimal and actual values of the sensors into account. Finally, we make a suggestion on how much irrigation percentage the irrigation system needs to run to give the plants enough water. We save water if this suggested irrigation value is not using 100% of the irrigation system.
We display this suggestion in the middle of the user interface, but for the actual farmers in the agricultural sector we could send this value directly to the irrigation system.
This is how our program saves water, and so reduces water waste.

If the soil moist sensor does not increase (or is back below 40% by the plant water usage), even though the program expected rain, the process will repeat it self until the soil moist sensor is once again above 40%.

It is more clear if you look at this example where the plant really needs water, but there is also rain expected. As you can see the suggested irrigation is not 100%, so we will save water.



On the Arduino itself, there are also multiple ways the farmer could see the data (so without the processing UI). First we have a LED that turns on when there is rain expected, according to the live API of Visual Crossing. We also have a OLED display that shows the temperature, humidity and the moisture of the soil. Finally we have a RGB LED that varies between green and red to show the humidity value. It is completely green when there is 100% humidity and it is completely red when there is 0% humidity.

For the validation of the live API of Visual Crossing we have used the history of several other forecasts [30][34], and compared it the history of the forecasts by Visual Crossing.
We looked at December 2021 and compared the results.

We looked at all the dates, but if we for example look at December 6, we can see that the our API is very close to the actual measured weather.

	Temperature	**Humidity**	**Rainfall**
Visual Crossing	2.6	92.55%	Slightly (8%)
Actual weather	2.5	95,75%	Slightly

After analyzing all the dates in December 2021, we came to the conclusion that the live API of Visual Crossing is 95% accurate.

If we look at everything we measured and validated, we can conclude that our program gives and displays many useful and accurate data, that farmers can use to manage their water, and so decrease water waste in agriculture.

This program could used on farms that have a fixed irrigation system, where always the same amount of water is given to the plants. The program is effective for multiple crops, in different countries under different conditions. As long as there is cheap and accurate weather data available.

(Discussion)
This project could be expanded by taking even more values into account, like sunlight, water quality and soil quality. Also it could be expanded so not only the agricultural sector can use the program, but also other groups of people that waste water. We definitely think that the cheap accurate weather forecasts is not used enough in the world, as it has so much potential to help all sorts of people to reduce water waste.
The worst part of our prototype is that the Arduino is connected to the laptop with USB, in a future improvement of this project people could make it so all the connections are wireless. Also, our prototype has one soil moist sensor which can very accurately sense the moisture in the soil, but only for a few plants. To expand this project we could connect our project to an entire field of crops and measure the results.

CultivAid

Appendix A: ArduinoJson

In this appendix we explain the use of the ArduinoJson library in our project.


```
{
  "latitude" : 52.2236,
  "longitude" : 6.89551,
  "resolvedAddress" : "Enschede, Overijssel, Nederland",
  "address" : "enschede",
  "timezone" : "Europe/Amsterdam",
  "tzoffset" : 1.0,
  "name" : "enschede",
  "days" : [ {
    "datetime" : "2021-12-14",
    "datetimeEpoch" : 1639436400,
    "tempmax" : 9.0,
    "tempmin" : 7.0,
    "temp" : 8.1,
    "feelslikemax" : 6.9,
    "feelslikemin" : 4.8,
    "feelslike" : 6.0,
    "dew" : 7.0,
    "humidity" : 92.9,
    "precip" : 0.0,
    "precipprob" : 0.0,
    "precipcover" : null,
    "preciptype" : null,
    "snow" : 0.0,
    "snowdepth" : 0.0,
    "windgust" : 24.8,
    "windspeed" : 15.9,
    "winddir" : 216.2,
```


Figure 1: JSON data

As you can see, weather forecast consist of a lot of information. We don't want our program to look at all the different data. For example it is not important for us how much wind there will be in one week, or how far you can see tomorrow. What is important however, is the amount of rain that is expected to fall this week.

Okay, so now we have the data and we know what parts of the data we will use. We also downloaded the ArduinoJson library so we should be able to simply convert our JSON data to Arduino. Well, it is not that simply, as the library we use is very complex. Luckily the maker of the library wrote an entire book about it [30] and made YouTube tutorials. There also is a very big website that explains all the documentation and it has a few tools to help you [29].

Using all this information we could make a small, but complex, program to test the library:

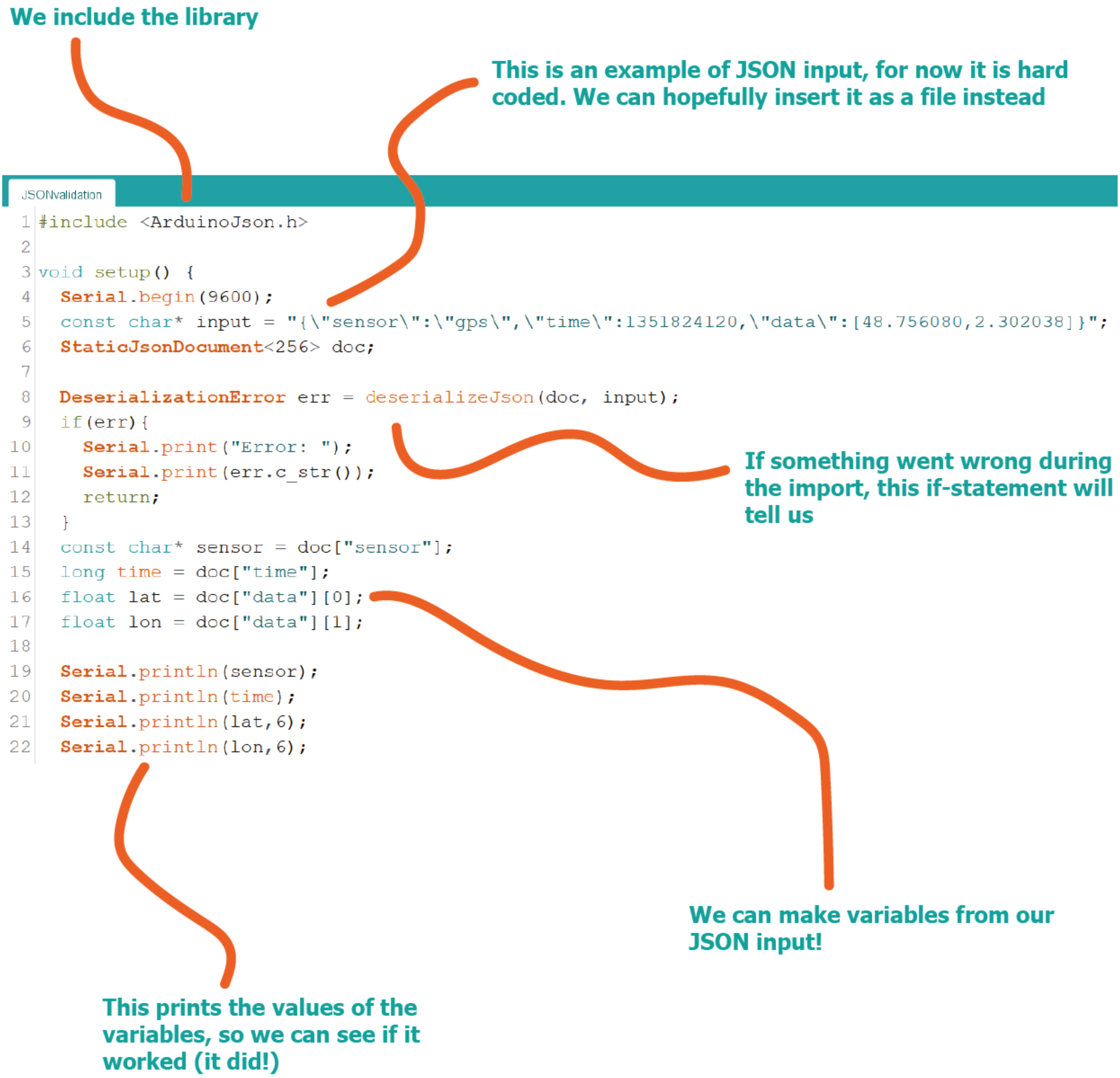


Figure 2: JSON conversion to Arduino

Okay this is the basis of the data conversion. The first problem now is that the data is manually inserted in the code, instead it would be better if we could insert the entire JSON file. Unfortunately this turns out to be very difficult, first off it will use too much memory on our computer. Secondly, we would have to make the Arduino communicate via Wi-Fi, which is very difficult and we would need separate equipment for that. So we decided that reading the Json code from a file will be part of our ambitious scenario.

Without the Json input from a file, the program will be less user-friendly. This is not a big problem as our program will behave the same way and we can still validate our program using hard-coded input. Our main priority should also not be making the best user-friendly program, it should be making a program that saves water in agriculture.

The second problem is that our data will be way too much for the Arduino if we use all of it as input. Luckily the ArduinoJson library has function that allows you to filter your Json document before actually deserializing (converting) it. This was difficult to implement, but in the end it luckily worked. This is our new code, that uses our weather data and uses a filter:

We include the ArduinoJson library so we can use its functions

This is our weather data from Visual Crossing, it is way too big for our Arduino, so we will use the filter functions from the library

JSONvalidationLargeFile

```
#include <ArduinoJson.h>

void setup() {
  Serial.begin(9600);
  while (!Serial) continue;

  const __FlashStringHelper* input_json = F("{ \"latitude\":52.2236, \"longitu

  // The filter: it contains "true" for each value we want to keep
  DynamicJsonDocument filter(200);
  filter["days"][0]["datetime"] = true;
  filter["days"][0]["humidity"] = true;
  filter["days"][0]["preciptype"] = true;

  // Deserialize the document
  DynamicJsonDocument doc(400);
  deserializeJson(doc, input_json, DeserializationOption::Filter(filter));

  // Print the result
  serializeJsonPretty(doc, Serial);
```

For now, we only want to see the date, humidity and preciptype (rain is a preciptype)

In the deserializeJson function, we make sure to let the program know we want to use the filter

Finally, we print the filtered results

Figure 3: Our data filtered in Arduino

This is (part of) the output of the program:

```
{
  "datetime": "2021-12-16",
  "humidity": 94.5,
  "preciptype": null
},
{
  "datetime": "2021-12-17",
  "humidity": 93.6,
  "preciptype": null
},
{
  "datetime": "2021-12-18",
  "humidity": 88.2,
  "preciptype": null
```


As you can see, our program tells us that the humidity will be very high on the 16th and 17th of December. But it is not going to rain in these days, if it would then the value of “preciptype” would be “rain” instead of null.
This is the end of the message:


```
      "preciptype": null
    },
    {
      "datetime": "2021-12-21",
      "humidity": 83.1
    }
  ]
}Error: NoMemory
```


Because we made the Arduino print errors (see figure 1) we get a message. The Arduino tells us that there is no memory left! This is luckily not the memory of the Arduino, but the memory of the deserialized Json document. We gave it a lower value so it will never break our Arduino!

Also we learned that a weather forecast has the best accuracy for the first 3 days, so we probably wouldn’t even need to know the humidity on the 21th of December (which is the 8th day for our program).

In the end, we decided not to use this library, even after spending a lot of time in it. A live data API is more accurate, and our Arduino has too little memory to use this library and all the sensors.

Bibliography

[1] Global News. 2021. B.C. floods put spotlight on Canada’s infrastructures. Improve them now, experts say | Globalnews.ca. [online] Available at: <https://globalnews.ca/news/8383793/b-c-floods-infrastructure-climate-change/> [Accessed 19 November 2021]..

[2] Rachel Ramirez, C., 2021. The shocking numbers behind the Lake Mead drought crisis. [online] CNN. Available at: <https://edition.cnn.com/2021/06/17/us/lake-mead-drought-water-shortage-climate/index.html> [Accessed 19 November 2021].

[3] the Guardian. 2021. US cities working to reduce emissions in the absence of bold action in Washington. [online] Available at: <https://www.theguardian.com/cities/2021/nov/19/us-cities-working-reduce-emissions> [Accessed 19 November 2021].

[4] De'ath, G., Fabricius, K., Sweatman, H. and Puotinen, M., 2012. The 27-year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Sciences, 109(44), pp.17995-17999.

[5] Q. Schiermeier, “Climate change made North America's Deadly Heatwave 150 times more likely,” Nature News, 08-Jul-2021. [Online]. Available: "https://www.nature.com/articles/d41586-021-01869-0"

[6] S. Leahy, “Thirsty future ahead as climate change explodes plant growth,” National geographic, 04-Nov-2019.

[7] Financing adaptation. Nat. Clim. Chang. 11, 887 (2021). https://doi.org/10.1038/s41558-021-01213-4

[8] Simpson, N.P., Andrews, T.M., Krönke, M. et al. Climate change literacy in Africa. Nat. Clim. Chang. 11, 937–944 (2021). https://doi.org/10.1038/s41558-021-01171-x

[9] Supran, G., Oreskes, N. The forgotten oil ads that told us climate change was nothing. The Guardian, The Guardian, 18 Nov. 2021 "https://www.theguardian.com/environment/2021/nov/18/the-forgotten-oil-ads-that-told-us-climate-change-was-nothing"

[10] Akdogan Z, Guven B. Microplastics in the environment: A critical review of current understanding and identification of future research needs [Internet]. Environmental Pollution. Elsevier; 2019 [cited 2021Nov19]. Available from: "https://www.sciencedirect.com/science/article/abs/pii/S0269749119302039?via%3Dihub"

[11] Cronin WB. The disappearing islands of the Chesapeake. JHU Press; 2005 Jun 17.

[12] Petrovic Z, Djordjevic V, Milicevic D, Nastasijevic I, Parunovic N. Meat production and consumption: Environmental consequences [Internet]. Procedia Food Science. Elsevier; 2015 [cited 2021Nov19]. Available from: https://www.sciencedirect.com/science/article/pii/S2211601X15001315

[13] Schramek, C. and Harmeling, S., 2017. G20 and Climate Change. time to lead for a safer future. [online] Geneva: CARE International, pp.1-17. Available at:

<https://careclimatechange.org/g20-climate-change-time-lead-safer-future/> [Accessed 23 November 2021].

[14] M. Ahmed, "Introduction to Modern Climate Change. Andrew E. Dessler: Cambridge University Press, 2011, 252 pp, ISBN-10: 0521173159", Science of The Total Environment, vol. 734, p. 139397, 2020. Available: https://doi.org/10.1016/j.scitotenv.2020.139397 [Accessed 23 November 2021].

[15] S. Clayton, "Climate anxiety: Psychological responses to climate change", Journal of Anxiety Disorders, vol. 74, p. 102263, 2020. Available: https://doi.org/10.1016/j.janxdis.2020.102263 [Accessed 23 November 2021].

[16] Anderson, R., Bayer, P. and Edwards, D., 2020. Climate change and the need for agricultural adaptation. [online] Science Direct. Available at: "https://www.sciencedirect.com/science/article/pii/S1369526619301219"

[17] Shen, M., Huang, W., Chen, M., Song, B., Zeng, G. and Zhang, Y., 2020. (Micro)plastic crisis: Un-ignorable contribution to global greenhouse gas emissions and climate change. [online] Science Direct. Available at: "https://www.sciencedirect.com/science/article/pii/S0959652620301852"

[18] Nina Howell, “Overpopulation: Causes, Effects and Solutions”, in Earth & Human, June 11th, 2020, "https://earthandhuman.org/overpopulation-causes-effects-solutions/"

[19] Moore, G. W. K., S. E. L. Howell, and M. Brady, “First Observations of a Transient Polynya in the Last Ice Area North of Ellesmere Island”, in Geographical Research Letters, August 18th, 2021, "https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL095099"

[20] “Water Scarcity in Africa: Issues & Challenges”, in Greentumble, September 20th, 2015, "https://greentumble.com/water-scarcity-in-africa-issues-and-challenges/"

[21] Wu, Katherine J. “It's Not You, It's Climate Change.” The Atlantic, Atlantic Media Company, 24 Nov. 2021, "https://www.theatlantic.com/science/archive/2021/11/albatross-divorce-climate-change/620795/"

[22] Austen, Ian, and Vjosa Isai. “Vancouver Is Marooned by Flooding and Besieged Again by Climate Change.” The New York Times, The New York Times, 21 Nov. 2021, "https://www.nytimes.com/2021/11/21/canada-flooding-climate-change.html"

[23] McGrath, Matt. “Climate Change: Extreme Weather Events Are 'the New Norm'.” BBC News, BBC, 31 Oct. 2021, "https://www.bbc.com/news/science-environment-59105963" .

[24] P. Balsom, “Water usage in the agricultural industry,” Htt.io, 28-Sep-2020. [Online]. Available: https://htt.io/water-usage-in-the-agricultural-industry/. [Accessed: 26-Nov-2021].

[25] “The world counts,” Theworldcounts.com. [Online]. Available: https://www.theworldcounts.com/challenges/planet-earth/freshwater/when-will-the-world-run-out-of-water/story. [Accessed: 26-Nov-2021].

[26] National Geographic Society. 2019. Noise Polution . [online] Available at: < "https://www.nationalgeographic.org/encyclopedia/noise-pollution/%3e" [Accessed 02 December 2021]

[27] The Hindu, "All about Hydroponics", YouTube, Dec. 17, 2020. [Video Recording]. Available: https://www.youtube.com/watch?v=wBcnUUkdavE

[28] V. Corporation, "Historical weather data for any location | Visual Crossing", Visualcrossing.com, 2021. [Online]. Available: https://www.visualcrossing.com/weather-history/enschede.

[29] "ArduinoJson: Efficient JSON serialization for embedded C++", ArduinoJson, 2021. [Online]. Available: https://arduinojson.org/.

[30] B. Blanchon, Mastering ArduinoJson 6. Antony: Benoît Blanchon, 2020.

[31] "Weather in December 2021 in Enschede, Netherlands", Timeanddate.com, 2022. [Online]. Available: https://www.timeanddate.com/weather/netherlands/enschede/historic?month=12&year=2021.

[32] "Understanding optimum Temperature and Humidity for Plants", London Grow, 2022. [Online]. Available: https://www.londongrow.com/blogs/grow-tips/understanding-optimum-temperature-and-humidity-for-plants.

[33] B. Gardening) and B. Strawberry Plant Flowers, "The Best Humidity Level for Plants (Plus How to Achieve It!) | GreenUpSide", GreenUpSide, 2022. [Online]. Available: https://greenupside.com/what-is-the-best-humidity-level-for-plants/.

[34] "Enschede Weather Charts", WorldWeatherOnline.com, 2022. [Online]. Available: https://www.worldweatheronline.com/enschede-15day-weather-chart/overijssel/nl.aspx. [Accessed: 30- Jan- 2022].