Technical University of Denmark

REPORT UN GOAL 15: LIFE ON LAND

42280 – SMART, CONNECTED, LIVABLE CITIES

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Group 15a

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1 Introduction

200 years ago, less than one billion humans inhabited the Earth. Today, according to UN calculations, there are over 7 billion humans living on earth – a population growth on an unprecedented scale in the entire previous history of humanity. A picture of our world population in 2050 projects a world that will be home to 9.7 billion people, a jump of roughly 2.6 billion. The changing of the world population is of great importance for humanity's impact on the Earth's natural environment, as it will catalyse increased urbanization and the sprawl of metropolitan areas. All over the world, an increasing part of the population is already living in urban environments. Yet, by 2050, 68 % of the population is projected to live within the urban realm - a trend that is tremendously shrinking the amount of farmland. In consequence, this urbanization causes severe environmental degradation, damaging biodiversity on a global scale.[1]

Furthermore, in the face of an increasing world population and with global hunger on the rise, the current global food production system raises concerns regarding the sufficient supply and accessibility of food. In fact, considering these key global trends calls for rethinking our food system in a way that it can feed the expected population and maintain global food production per capita in the future. In attempting to create new ways of promoting food production, urban farming could be an emerging movement that fosters an integrating sustainable food-system within the design of urban environment.

The following report explores the potentials of implementing urban farming as a sustainable food system that includes infrastructure and processes for feeding an urban population with the help of smart technologies. By inserting food production entities into the urban realm, it proposes a solution that not only supports future farming that secures biodiversity, but also a shift in how we shape and perceive our urban environment. Smart urban farming could provide the opportunity of transforming our communities and cities into better places to live, learn, and work, by fostering urban regeneration and social engagement in the neighborhoods. The holistic approach of our urban farming concept targets to educate urban societies in agricultural practices and aims to contribute to a sustainable community. Most importantly, our solution envisions urban farmland that is cultivated in a sustainable way ensuring biodiversity and therefore contributing to fulfilling the United Nations (UN) - Sustainable Development Goal 15: Life on Land. It is to result in a food system that supplies healthy and nutritious food accessible and in close proximity to the people living in cities.

Before introducing our proposed solution, it is important to discuss the UN Development Goal 15: Life on land, its concept of ensuring biodiversity and how the loss of biodiversity correlates with increased urban sprawl.

[1] UN World Urbanization Prospects (2018): p.1

2 UN SDG 15: Life on land – biodiversity

Chapter two introduces the chosen Sustainable Development Goal (SDG) 15 focusing on biodiversity as part of the SDG catalogue launched in 2015. It defines the term biodiversity for further discussion and how to measure it before addressing the effect of urbanization on biodiversity. With the launch of the UN SDGs in 2015, the world community has set the agenda for targeting the humanity's most pressing challenges, including ending poverty and ensuring prosperity for the growing world population. All while keeping in mind and respecting planetary boundaries. It addresses several challenges that are grouped into individual development goals. The SDG of choice is SDG 15, which encompasses and aggregates aspects regarding life on land including the protection of forests, combating desertification, and preservation of biodiversity. The proposal of our Internet of Things (IoT) based solution serves to work towards fulfilling the aspect of biodiversity targeted by the SDG 15.[2]

As of 2015, over 23,000 species of plants, fungi and animals were known to face a high probability of extinction according to UN research indicating a biodiversity decline worldwide. There is considerable evidence that the stable functioning of ecosystems depends heavily on biodiversity. Studies have been conducted showing that ecosystem functioning often depends on species richness, species composition and functional group richness. Hence, biodiversity loss could diminish human wellbeing by decreasing the services that ecosystems provide for people. Simply put, the air we breathe, the water we drink and the food we consume all rely on biodiversity. An obvious example is that without plants there would be no oxygen and without bees to pollinate the plants there would be no fruit or nuts. There are countless other interactions within ecosystems that if undamaged produce a finely balanced healthy system which contributes to a healthy, sustainable planet. Thus, it is highly relevant to mitigate the decline of biodiversity.[3]

When it comes to the term Biodiversity it might be difficult to grasp its full extent, as it is a broad term used in many ways and viewed from different perspectives. People often associate biodiversity with abundance of species or wild places, however, it surpasses that by far. The Convention on Biological Diversity gives a formal definition of biodiversity in its article 2: "*biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*". The definition itself is again so broad that it can only be fully understood by considering three different levels of Biodiversity: species diversity, genetic diversity and ecosystem diversity. These levels are explained as follows:

1. Species diversity refers to the variety of different species such as palm trees, elephants or bacteria.
2. Genetic diversity corresponds to the variety of genes contained in plants, animals, and microorganisms. It occurs within a species as well as between species. For instance, poodles, german shepherds and golden retrievers are all dogs, but they all look different.
3. Ecosystem diversity refers to all the different habitats – or places – that exist, like tropical forests, hot and cold deserts, wetlands, rivers, mountains or coral reef. Each

[2] https://www.un.org/sustainabledevelopment/biodiversity/ 25.11.2018
[3] Naeem et al. 2009: Biodiversity, Ecosystem Functioning and Human Wellbeing: An Ecological and Economic Perspective p.30 ff

ecosystem corresponds to a series of complex relationships between biotic (living) components such as plants and animals and abiotic components which include sunlight, air water, minerals and nutrients. [4]

After defining the term biodiversity it is important, to determine indicators to measure biodiversity in order to monitor and assess changes. Yet, measuring such a broad concept in useful ways poses a challenge. For different methods exist for assessing biodiversity and determining whether biodiversity has changed. In fact, biodiversity can never be fully captured by a single number. However, it is a common method to measure two different indicators: the species richness as in the number of species in a specific area and the number of species and the relative abundance of all species. These indicators are considered to serve well for our urban farming system.[5] Rates of species extinction continue to increase and the number of threatened species continues to grow. Thus, biodiversity is declining – A development that is promoted by human activities that are fundamentally changing the diversity of life on the planet part. Urbanization is part of these human activities that often cause biodiversity decline.[6]

As urban sprawl and cities continue to grow, vital habitat is being destroyed or fragmented into patches not big enough to support complex ecological communities. Species may become locally extinct, as previously natural areas are swallowed up by urbanization. In the United Kingdom for instance, an increasing human population density, and the resulting increase in urban development, were found to be the cause of 35 % of scarce plant species extinctions in the counties surrounding urbanized areas. Similarly, in the United States, urbanization has been found to be directly responsible for the endangerment of 275 species.[7] Population growth is driving the expansion of urban areas which is taking up a considerable amount of land area. Thus, habitat is being destroyed which results in a decrease of both richness and abundance of native species, including plant, mammals, insects and amphibians.

Closely related to habitat loss is habitat fragmentation, which can be defined as the transformation of a large and continuous habitat into many smaller, isolated habitats. The expansion of cities causes the fragmentation of large areas of natural habitat through the construction of roads, houses and industry. In many cases, all that remains are small remnant patches of the original habitat contained within the confines of the city. Biodiversity is greatly reduced when large areas of natural habitat are fragmented. Small habitat patches are unable to support the same level of genetic diversity as they formerly could, while some of the more sensitive species may become locally extinct.

As our proposed solution is designed to serve as an incentive to mitigate biodiversity loss and hence targets SDG 15: life on land. However, it also tackles several sub-targets that are part of other SDGs which is addressed in chapter three.

[4] T Edward O. Wilson BioScience, Vol. 35, No. 11, The Biological Diversity Crisis (1985), pp. 700-706
[5] Perspectives on Biodiversity: Valuing its Role in an Everchanging World (1999) p.20 ff ->report committee on noneconomic and economic value of biodiversity
[6] McDonald et al. (2013): Urbanization and global Trends in Biodiversity and Ecosystem Services, p.36
[7] Czech et al. (2004): Urbanization as a Threat to Biodiversity: Trophic Theory, Economic Geography, and Implications for Conservation Land Acquisition (Symposium)

3 Urban farming

The following chapter presents and defines the concept of Urban Farming. Furthermore, different techniques of Urban Farming as well as trends and problems the concept is facing and will face in the future are examined.

3.1 What is urban farming

In general, urban farming has been developed to ensure food production in a world with almost 10 billion people by 2050 and increasing urban areas. The trend of urbanization will lead to an incredibly high amount of nearly 80 % of people living in urban centres. If traditional agriculture techniques will continue, an estimated area of 10^9 hectares is needed to feed these people.[8] To solve this problem, urban farming solutions have been developed in various ways including more efficient space usage and high-end technology. In addition to ensure food security in the future, urban farming also contributes to the distribution problem regarding conventional food production. This problem is generally known as food miles which means that on average, food has to travels more than 2,400 km from the growing farm to the consumer. By ensuring locally produced food, urban farming is able to cut up to 60 % of the costs of food and reduce energy waste due to ceasing distribution.[9]

According to Poulsen and Spiker (2014)[10], urban farming is the activity of agriculturing in an urban area with an emphasis on food production. The focus lies on the commercial cultivation and distribution of food, but in the present report it also includes growing and consuming the food by growers themselves which is a slight difference from the definition of Poulsen and Spiker. The food can be distributed in various ways such as local farmers markets, organic local supermarkets, in the garden, but people could also get it in the menu of local restaurants.

Urban farming already plays a non-negligible role in our cities. Contributing to the urban economy, six percent of the global farmland is located in cities with more than 50,000 people.[11] Farming in an urban area hereby incorporates different functionalities and is therefore able to add diverse value to the urban economy and society. Next to the production, other service functions as recreation, education and health are considered as the functional dimension of urban agriculture. In urban areas, there are different urban agriculture concepts, such as allotment gardens or educational gardens in universities, mostly addressing only one function. Urban farming on the other hand is defined by its multifunctionality addressing on-site services as well as services for the urban environment. On-site services might be leisure, educational, therapeutical and social, whereas food production and environmental services have beneficial characteristics for the urban economy, biodiversity, air quality or environment flows.[12]

There are two main different techniques when it comes to urban farming which will be explained in the further course of this chapter. Firstly, horizontal urban farming, and secondly, vertical urban farming which could play an important role in the future considering the concept of smart urban farming. Furthermore urban farming can be differentiated concerning various

[8] D. Despommier, http://www.verticalfarm.com/
[9] K. Al-Kodmany (2018), p. 1
[10] Poulsen et al. (2014) : Integrating Urban Farms into the Social Landscape of Cities, p. 3 ff.
[11] Thebo et al. (2014), p. 7
[12] F. Lohrberg et al. (2015), p. 19 ff.

aspects such as the growing medium, the water source, but also the location (meaning indoor, outdoor, roof or even underground)[13].

3.1.1 Horizontal urban farming

When talking about horizontal urban farming one automatically comes across the term of Urban Gardening. In the literature these terms are very often used as synonyms because both of them refer to gardening activities as well as food production in urban areas. However, they are slightly different as urban gardening concepts and initiatives rather focus on the social aspect to strengthen the sense of community in the respective neighbourhood and therefore to increase life quality through green spaces where one can also pursue one's hobby[14]. Besides that, the importance of aesthetics for the surrounding area is another major aspect when talking about urban gardening. In the further course of the present report, the focus is put on urban farming, whereas concepts of urban gardening are not considered.

Horizontal urban farming is therefore the basic technique of urban farming where food production is horizontally spread over the surface area in dense urban areas. That can be in backyards, on rooftops but urban farming can also be done in any other free space within the city boundaries.

There are various benefits of this concept, including environmental, economical, social and health benefits presented as follows[15]:

- ❏ Improvement of the air quality within the the city (increase of the photosynthesis rate, reduction of emissions caused by the food transport),
- ❏ Reduction of sealing which leads to an increased rainwater drainage,
- ❏ Increased biodiversity,
- ❏ Noise reduction,
- ❏ Job creation,
- ❏ Cultural integration,
- ❏ Education,
- ❏ Community development,
- ❏ Contribution to aesthetics of the city,
- ❏ Easy access to local, organic vegetables which leads to a better health of people[16].

A problem that can be associated with horizontal urban farming however is that this concept is at present only an addition to the food production and does not yet have the power to provide complete cities with local vegetables, fruits, herbs or even animal-based products such as eggs. Nevertheless, the concept has potential to fight hunger and especially in developing countries with a large gap between the wealthy and the poor, urban farming on a small scale is an affordable option for the people living in poorer conditions in metropolitan cities[17]. Another challenge horizontal urban farming faces at present is that it is not more efficient than the traditional farming in rural areas. It only uses the space available anyway and therefore only contributes to an efficient space use whereas vertical urban farming which is examined in the

[13] Tefft et al. (2017) : Food systems for an urbanizing world
[14] Tobisch (2013) : Oasen im Beton, p. 26
[15] Poulsen et al. (2014) : Integrating Urban Farms into the Social Landscape of Cities, p. 4 ff.
[16] Poulsen et al. (2014) : Integrating Urban Farms into the Social Landscape of Cities, p. 4 ff.
[17] Tutmann (2018) : Wie Urban Farming die Welt ernähren wird http://www.faz.net/aktuell/race-to-feed-the-world/in-kapstadt-wachsen-moehren-und-hoffnung-15870998.html

further course of this chapter increases the efficiency of farming itself. According to Lin et al. using fertilizers excessively can have a negative impact on the soil in the city, thus is a major disadvantage of horizontal urban farming. It is therefore important to control the use of chemicals in order to prevent pollution.

To illustrate the concept of horizontal urban farming, in particular rooftop farming, the Copenhagen Østergro project is a good example[18]. Vegetables and herbs are grown on a 600 m^2 open-air field on the rooftop of an old car-auction house. In addition to that, Østergro even keeps hens for eggs and three beehives in order to produce honey. It is important to mention that the project not only provides Copenhagen with local food but it also offers high quality meals for those who are interested, in a small greenhouse that is set up as a restaurant on the rooftop. Østergro is profit-oriented but it focuses on the social rather than the economic aspect which is illustrated not only by the wide range of food-workshops and other events they offer but also through the volunteers that mainly work on the farm[19]. The main goal is furthermore to point out and promote the importance of environmentalism to the society. This initiative is with its holistic approach a great way to promote urban farming and has potential for the future.

3.1.2 Vertical urban farming

Horizontal farming is using space which would usually not be used and transform it into an productive space for farming and communal activity simultaneously contributing to our environment. On the other hand, vertical farming has been developed as an alternative to solve the food problem, introduced above. Dickson Despommier further developed the idea of urban farming and maximized the space efficiency for food production by planting vertically. By definition, vertical farms are indoor farming models where plants grow in a controlled environment and water usage can be minimized by 95 %, compared to traditional agriculture using new technologies as Hydroponics or Aeroponics. Both methods for growing food are soil-free with hydroponics using nutrient-enriched water as the growing medium and Aeroponics spraying a mist of nutrient solution over the roots of the plant. Both methods favour rapid plant growth and decrease the use of pesticides. Typically, this kind of vertical farming is used on tall vertical structures with growing trays in several levels using artificial light in the exact frequency and spectrum as it is best for the growing process of the plant.[20]

The following benefits come along with the concept of indoor vertical farming[21]:

- ❏ Year-round crop production,
- ❏ Significantly reduced use of fossil fuels (farm machines and transport of crops),
- ❏ Makes use of abandoned or unused properties,
- ❏ No weather related crop failures,
- ❏ Sustainable farming solution for urban areas,
- ❏ Creates new urban employment opportunities,
- ❏ No need for pesticides and other chemical agents used in traditional agriculture,
- ❏ Returns farmland to nature, helping to restore ecosystem functions and services.

[18] Grospiseri, https://www.grospiseri.dk/the-rooftop-farm/
[19] Hoops et al. (2018) : Copenhagen's Case for Urban Farming: A Feasibility Study, p. 9
[20] K. Al-Kodmany (2018), p. 7 ff.
[21] D. Despommier, http://www.verticalfarm.com/

The advantages of vertical urban farming are rich and sound convincing. However, there are also disadvantages with this concept that have to be solved in order to make it a holistic solution to ensure food security in the future. The most important challenges are the operational costs, especially the costs of electricity for the artificial lighting, which have a large impact on the profitability.[22] Therefore a solution has to be developed which includes all benefits of vertical farms and is still economically sustainable.

Besides the indoor concept using a lot of electricity, vertical urban farming on facades of high-rise buildings is another possible concept for urban farming. Yet, no elaborated research has been done to use this type of farming for food production. One example of growing plants (even trees) on the facade of a building is the Bosco Verticale in Italy, a vertical forest with 900 trees and 11,000 floral plants which is shown in Figure 1. In addition to its phenomenal aesthetics, Bosco Verticale and it's flourishing trees help to improve air quality, provide shade and reduce noise pollution.[23]

Figure 1: Bosco Verticale in Milan, Italy[24]

An alternative focusing more on outdoor urban farming is introduced by Bright Agrotech LLC in Wyoming with the ZipFarm (Figure 2). The CEO recently said that "Vertical surfaces are really one of the most undervalued types of real estate in the world" which are barely used for more than advertising. Zipfarm tackles this potential by installing a lightweight vertical tray system which act as the growing medium for different kinds of plants. Besides being self supporting on several types of facades and automatically supply the plants with water and nutrients, these vertical farms also act as energy-saving, air-cleaning living art. ZipFarm aims to become a small scale urban farming solution for private persons as well as a big scale solution for commercial use. Its flexible and space efficient design allows to use the farm both outside and inside using artificial light.[25]

[22] G. Hoops et al. (2018), p. 9
[23] ARUP project description in: https://www.arup.com/projects/bosco-verticale
[24] https://www.stefanoboeriarchitetti.net/en/project/vertical-forest/
[25] H. Angel (2015), http://arquitecturaverdeinteractiva.blogspot.com/2015/10/these-vertical-farms-turn-unused-city.html

Figure 2: ZipFarm Vertical Farm wall[26]

3.1.3 Trends

Urban farming solutions are growing in an incredible fast pace and many start-ups have been founded in this area. Especially in the vertical farming sector, more and more smart technologies are used to optimize the efficiency of farms.[27]

One of the very promising solutions in this case was developed by AeroFarm: *The Smart Vertical Farming Innovation*. Through the implementation of smart technologies, AeroFarms became the commercial leader for indoor farming. Their farms are using innovative aeroponic systems with sensors identifying all needs of the plant in order to optimize the predictability of the harvest and of the food quality. Besides controlling and monitoring the water, nutrients and the fertilizer supply as basic needs of the plant, this vertical farm solution also includes other technologies to assist the growing process. Examples for this are humidity control, temperature control as well as artificial lighting. Furthermore, it ensures faster harvesting periods and less impact on the environment. Aeroponic systems require neither any substrate as soil nor sunlight. Plants grow with their roots suspended in an air chamber where a fine mist of nutrient solution is sprayed to supply the plants with everything they need to grow. Figure 3 shows the technology of AeroFarm.

[26] https://aerofarms.com/technology/
[27] K. Vyas (2018), https://interestingengineering.com/13-vertical-farming-innovations-that-could-revolutionize-agriculture

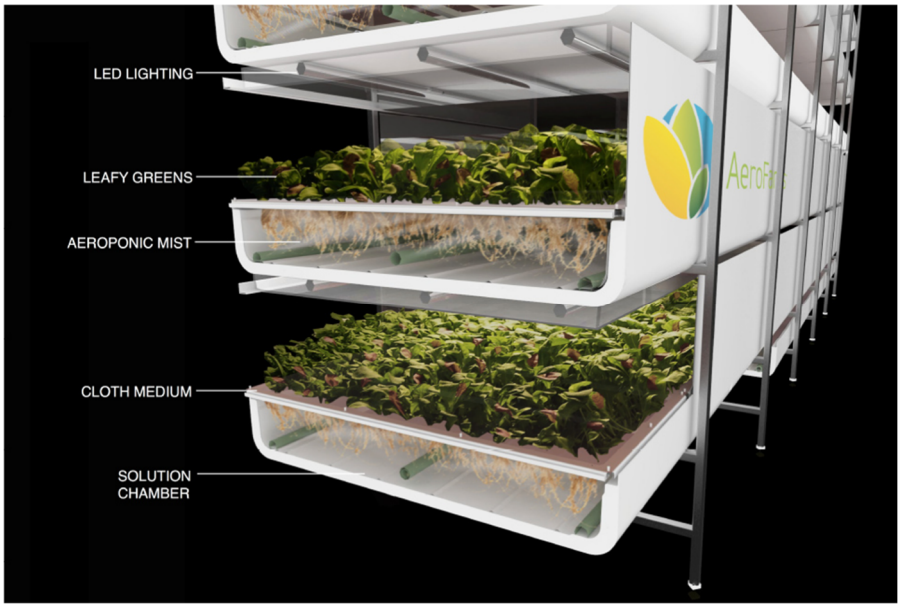

Figure 3: AeroFarm Technology[28]

To ensure and control the results of the farm, AeroFarms implemented smart light, smart aeroponics, smart nutrition, smart data, smart pest management, smart substrate and smart scaling. With that, they intend to transform the entire agriculture system and provide nutritious, safe and sustainable food through local production by building environmentally friendly, vertical farms around the world.[29]

One of the most sustainable and high potential approaches for high-tech indoor farming is the closed-loop agricultural ecosystem, where all the accruing waste during the farming process will be handled as a welcoming resource for another process. Thus, a small ecosystem is created within the borders of the urban farm, mimicking a well functioning natural ecosystem. Biodegradable waste from the harvest will be composted and used as a highly nutritious growing medium for other plants. Other solutions also combine aquaculture (fish farming) with agriculture creating a highly efficient symbiotic relationship between both systems. The nutritious waste water from the fish is used as a fertilized medium for the plants. On the other hand, plants are cleaning the water from chemicals and acids, so it can be reused for fish farming purposes. Closed-loop systems aim to reuse nearly every element of the farming process in order to keep everything within the small ecosystem. This leads to almost zero-waste as well as the potential to produce valuable resources or even bio-energy.[30]

In this specific case, considering SDG 15, vertical indoor farms are less applicable, because they operate in a closed environment and are not open to nature. Thus, bees and other insects are excluded and the main goal, to increase biodiversity, is not tackled. However, innovative solutions developed for vertical indoor farms can be adapted to outdoor farming. Especially smart technologies enabling (remote) monitoring and control, closed loop watering systems and controlled nutrient supply are promising features for the outdoor application.

As research reveals, IoT-based, smart technology has also a great potential in conventional farms. One application of IoT could be the detection of pests with a cloud computing smart

[28] http://blog.zipgrow.com/beyond-beauty-a-living-wall-for-todays-food-landscape/
[29] AeroFarms: https://aerofarms.com/
[30] K. Al-Kodmany (2018), p. 12 ff.

farming system, as demonstrated in an Indian research paper. In this research, wireless video cameras are used to scan a tomato field, which is shown in Figure 4, and send the data to a cloud, where it is processed with a pesticide database as well as a java application in order to detect the pest. Based on the type and number of pests, an adequate amount of pesticide can be sprayed to the affected plants.[31] In the paper, this solution is developed only at a small scale, but it reveals the potential behind IoT applications in the agricultural sector.

Figure 4: Possible setup of a smart camera[32]

Other papers show, that farmers using IoT-systems to improve their farming activities with different smart farming solutions already exist. IoT-systems are able to monitor the environmental conditions and automatically control smart devices based on the extracted data through a wireless network. Furthermore, it allows the farmers to monitor and control the operation of their farms remotely through mobile devices. The following research uses this existing solutions and develops interoperable and connected smart solutions for farming activities. The paper demonstrates that the development of IoT is not only beneficial to the single smart farm which is equipped with different types of smart devices. IoT also allows to create smart platforms connecting several smart farms and take advantage of experts' farming knowledge, enabling even people with little farming experience to professionally grow plants.

In this case a three level structure is used to transmit the data from the sensors to the end user. Sensors for temperature, humidity, CO_2, illumination and controllers for sprinkler, LED lights, air conditioners and heater are constantly monitoring and controlling the environmental condition of the farm. The created data is then collected by the installed IoT gateway and transmitted to the IoT service platform where the data will be translated into a virtual representation. This enables the end user to receive the data in a structured and visualized way. The expert knowledge can either be provided by using an existing knowledge base (like IBM Watson) or by having experts interacting with the user in order to build up a new knowledge base as the farming continues. A major advantage of this system is the interoperability using secure IoT systems and methods which can be adopted in almost every farm. As soon as all smart devices are connected to the smart platform, farmers have access to monitor and control their farm remotely. A practice example could look like this: "If the soil

[31] Sudhir et al. (2015), p. 1 ff.
[32] R. Sudhir, T. Varsha (2015)

moisture sensor uploads a particular value less than a threshold suggested by the knowledge base, the farmer receives an alert message, and triggers the irrigation system immediately"[33].

Through the connected smart farm system, farmers can benefit both from the monitoring and controlling ability on their farm and, more importantly, use a constantly growing farm expert knowledge base in order to get the best outcome of the farm.[34] This idea, using a connected farm platform where several experts and amateurs can interact and share their knowledge, has a high potential for the future of farming. Besides that, more and more agricultural monitoring systems as the pest detection, presented above, are developed which can be implemented into the smart platform.

3.2 Sub-targets of urban farming

Urban farming and biodiversity

Urban farming has positive impacts on various areas including the environment concerning the climate change mitigation. It has the potential to preserve and even drastically increase biodiversity within a city. Urban farms not only increase the number of plant species but they also increase the overall coverage of plants in the city[35]. Therefore urban farming contributes to the reduction of sealing and makes a cultivation of brownfields and unused spaces such as rooftops possible. Furthermore, through more urban farms, the number of animal species as well as the number of individual animals within a species increases which is a very important goal concerning SDG 15.

Smit (n.y.) explains the increase in biodiversity on urban farms in relation to rural farms through the more diverse crop mix on a smaller area[36]. Another reason for the increase in biodiversity is said to be the focus on a more sustainable and organic food production. Urban farming however can also have a negative impact on the biodiversity, when not focussing on the biologically friendly production very much and using chemicals for fertilizing[37].

Indoor vertical farming is another technique of Urban Farming and does not lead to an increase of biodiversity.[38] It focuses on the commercial aspect of Farming and therefore only aims for the food production in a closed and controlled environment that has the best infrastructure for the food to grow.

Urban farming and food production

Food is the basic need of every human being. The food production, especially in the agricultural sector, has changed over the past years and urban farming is a modern way of food production, in particular plant foods, in dense, urban areas. It focuses on a rather local distribution, encourages the organic growing process, and therefore promotes sustainability. Due to these aspects it can be argued that urban farming increases the food quality and has therefore also a positive impact of people's health[39].

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[33] M. Ryu et al. (2015), p. 4
[34] M. Ryu et al. (2015), p. 1 ff.
[35] Lin et al. (2015) : The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps, p. 192 ff.
[36] Smit (n.y) : Urban Agriculture and Biodiversity – Urbanisation and Diminishing biodiversity, p. 2
[37] S.a.
[38] D. Despommier, http://www.verticalfarm.com/
[39] Project - targets, definitions & indicators - assignment 5

Urban farming can be scaled according to the needs of the local population. Small communities, often in a poor financial situation and with lack of access to food distribution channels and often in developing countries, resort to locally grown food to supply the immediate nutritional needs to the community (think of growing staple cereals and legumes and less-extended animal husbandry in remote communities across the world; less needed products, such as specialised agricultural produce can be obtained in larger centres, covering a larger population. This kind of practice can further contribute to achieving and is in line with the targets of UN SDG 2 – zero hunger.

Urban farming and education

When examining Urban Farming and its links to other relevant topics concerning the SDGs, one comes across education as urban farming can be a teaching resource and urban farms can act as natural laboratories[40]. As shown in the example of the østergro-project in Copenhagen urban farming can have a positive impact on the education of people. By providing farming workshops there is an opportunity for people to learn how to grow food and therefore to acknowledge important side effects such as biodiversity and air pollution and how a deterioration of them would affect the food quality[41]. Consequently, urban farming could rise the level of awareness about agriculture, in particular food production and food origin in urban areas and promote the importance of sustainable development for the future through education[42]. These benefits clarify that education about farming should be implemented in every level of school and urban farms could act as a laboratory in urban areas away from the rural farms. Education can, especially in developing countries, make a significant difference in the decrease of the worldwide hunger as educated people would be able to provide food for themselves.

Urban farming and climate change

Urban farming is an important part of the strategy for climate change adaptation. Urbanization and climate change are closely connected, as the main part of greenhouse gasses are emitted in urban areas. The effect of the climate change is getting more and more noticeable, where key issues are including rising temperatures, increasing flooding and storms, and where food quality and quantity is constantly becoming more uncertain. Cities play an important role in climate change adaption, as they take up larger areas of the earth every year. By increasing the vegetation, the water infiltration capacity of the soil is improved, and by doing so, cities can adapt to future needs in case of a storm. When the water infiltration capacity is growing, groundwater table can rise, which will then give cities benefits towards drought resistance[43].

Urban areas are already measurably warmer than their surroundings, due to increased built-up areas and decreasing green areas. In the concept of urban farming, planting more vegetation can also provide shade and increasing evapotranspiration. Plants and trees can give cities the advantage of a cooling effect, as the world heads towards a warmer future. Urban greening can also help to reduce energy demand for cooling of buildings[44].

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[40] F. Lohrberg et al. (2015), p. 127
[41] F. Lohrberg et al. (2015), p. 24
[42] F. Lohrberg et al. (2015), p. 209
[43] https://climate-adapt.eea.europa.eu/metadata/adaptation-options/urban-farming-and-gardening
[44] https://www.ruaf.org/sites/default/files/Policy%20brief%20Urban%20agriculture%20as%20a%20climate%20change%20strategy.pdf

Urban farming and economy/society

Urban farming can both be small farms in cities or a cohesive neighbourhood sharing a food garden, where vegetables and fruits can be grown to provide food for their residents. Urban farms produce food, but they also give an opportunity to form a society around them. It can be used as a classroom, ecosystem service benefactors and much more. As the farms could be run by people who are not only farmers, but people who can educate others and show unqualified individuals how to grow their own food. School children could, from a young age on, learn how to take care of plants and grow their own food. Where the farmers could help create a better understanding of agriculture, which could lead to better awareness of the importance of vegetation[45].

The urban farming must compete with the supermarkets around the area on price and quality, where it could be an advantage if they differentiate themselves from the standard fruits and vegetables. Vegetables as cucumber, tomatoes etc. are often very cheap in the supermarket, depending on the area. Hence, it could be an advantage to differentiate themselves by variety, quality or price, by for example having other types of tomatoes than typically found at the markets. More expensive vegetables are often costly because of the difficulties of harvesting them, but it can also be because of the long distances they have to be transported before reacting the markets. This gives the urban farms another advantage, selling the fruits and vegetables straight from the farm, and can thereby lower the costs, by controlling several steps of the supply chain.

The urban farms are connecting food with people and open for an opportunity to offer more than just food. The community around the farm has a possibility to be a part of the process, as volunteers or as a part of education. The urban farms can offer volunteer positions to help out at the farm which includes to help with planting, cropping and harvesting. Another possibility could be to organise festivals or events that bring people together to learn about the processes and the food that the farm produces, so everybody gets a chance to know their local farm. As part of education the farm can offer educational days, or special programs for schools, to teach children about the importance of agriculture, and how to grow their own food. Apart from the food the education can also teach children or adults about biodiversity, because the farms can show a variety of plants and insects that live on the farms.[46]

[45] (PDF) The Urban Farming guidebook
[46] (PDF) Urban Agriculture Europe

4 Smart urban farming

Chapter four explains smart technologies that can be implemented in smart urban farming. As shown in chapter 3.1.3, many of these technologies are already used as a part of the current fast development in the urban farming sector. Moreover, smart platforms which can be used as an interface for urban farms, including a farming app, are analysed.

4.1 Smart technologies

In order to further increase the benefits of urban farming, we put forward several smart technologies that can enhance productivity, provide valuable insight into plant and insect life, and help users and other parties take full advantage of the concept of urban farming. While there already are existent technologies and solutions on the market, as referenced in the chapters to follow, we make a holistic proposal, taking into account users' needs, technology requirements and final output. The technologies have proposed individual indicators as well, but the final indicators are to be decided once the solutions are implemented and suited to the client. A brief overview of possible indicators for the report can be found in the appendix 1.

4.1.1 Biodiversity cameras

One smart technology that can be implemented in a system of urban farms is a smart camera that could look like the one shown in Figure 5. These smart cameras, set up properly and using a well-designed system of recording input, communication platforms and valuable output, can enhance the already beneficial concept of urban farming.

Figure 5: Biodiversity camera[47]

Cameras can be used to monitor a plant's needs and health. Already popular in the field, infrared cameras prove to be one of the most efficient. The necessity of an infrared camera comes from the physiology of plants. In the process of converting sunlight into sugars, plants absorb red and blue light, as part of the light spectrum. Since infrared light is not absorbed, however, cameras can help compare infrared with visible light to show how productive the plant cells are[48].

[47] https://www.hobbytuxtla.com/drones-camara-sensor-multiespectral-sentera/
[48] Infragram Plant Cam

To get the infrared camera system started, photos have to be taken, as a parameter and setting a common basis for the cameras to work: Near-infrared images and regular visible light images of the same scene (or an image which combines these in different colour channels) (Figure 6). The process needs to contain a software or an image processor that can understand the near-infrared pictures taken by the camera, and an analysis, such as tips and support to interpret and understand what the images are telling.

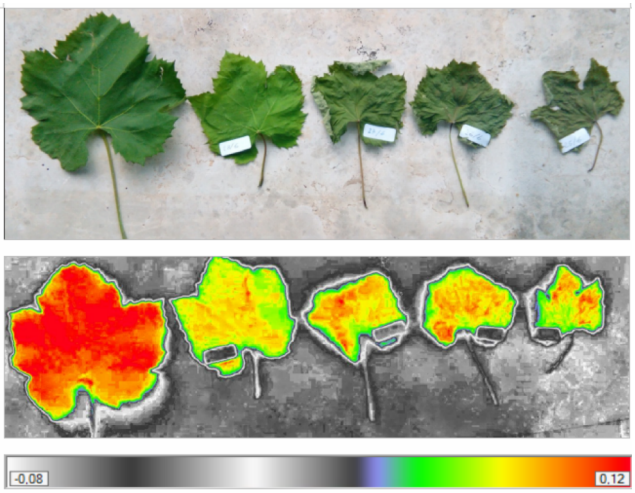

Figure 6: Leaves photographed with infrared camera[49]

Doing NDVI[50] analysis on plants requires post-processing both infrared and visible images. NDVI stands for "*Normalized Difference Vegetation Index*". NRG is defined as "*Near-infrared/ Red/ Green*". NDVI and NRG are both ways to visualize the amounts of infrared and other wavelengths of light reflected from vegetation. Because both these methods compare ratios of blue and red light absorbed versus green and IR light reflected, they can be used to evaluate the health of vegetation. NDVI is a ratio which tries to emphasize photosynthesis while filtering out sun glare (Figure 7). The result can be false-coloured to make the high-photosynthesis areas more clear, and used to examine where plants are and how healthy they are. It is a snapshot of how much photosynthesis is happening[51].

[49] http://physicsopenlab.org/2017/01/30/ndvi-index/
[50] Basso, Bruno, et al. "Spatial validation of crop models for precision agriculture." *Agricultural Systems* 68.2 (2001): 97-112.
[51] Li, Yurui, et al. "Dynamic analysis of ecological environment combined with land cover and NDVI changes and implications for sustainable urban–rural development: The case of Mu Us Sandy Land, China." *Journal of Cleaner Production* 142 (2017): 697-715.

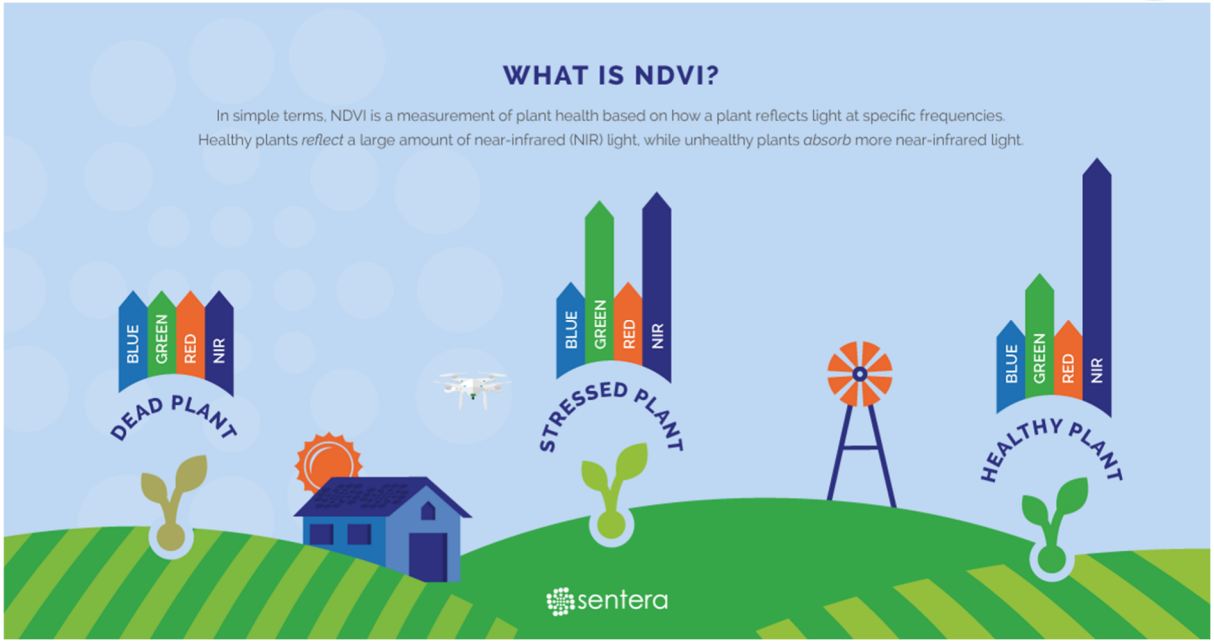

Figure 7: NDVI infographic[52]

The software can furthermore be set up so that it sends information when the plant is doing badly, based on the amount of near infrared light it reflects. It can send notifications as alerts, informing members of a distribution or subscribers' list of need to attend to the plants. This setup can be incorporated into the software's programming language or script (example: Pushover service[53], simple, but highly customizable API).

Indicators can as well be developed, such as a health indicator, measuring the number of sick plants out the total planted ones (unit: number; the lower the number, the healthier the crop is). The data can be stored, it can serve for research purposes or it can be used to determine trends in regards to the plants' health.

An additional role that cameras could have is to provide information about the quality of the food or produce. Similar to the previous case, when the cameras monitor plants' health, the software used in this case would be to be setup with a database of parameters that designated the quality of the food. For example, the ripeness of a vegetable can be measured. The input from the camera (colour of the vegetable) can be measured against a previously set Red Green Blue colour code (with tolerance margin, since the vegetable can be ripe for a longer period of time). A possible indicator could be the production level, measuring the number of ripe vegetables collected in the expected maturing period (unit: number; the bigger the number, the more productive the crop is) or the crop efficacy indicator, measuring the number of ripe vegetables out of the total against the maturing time (unit: number/time; the higher the number, the better the crop yields).

Last but not least, cameras can also be set to identify species of insects and plants. This especially applies for outdoor urban farms, placed on rooftops or on empty or unused plots. It is needless to say the importance insects have for a healthy botanic environment. Some insects can damage crops, but others also provide pollination and pest control services, or improve the fertility of the soil through feeding on and assisting the decomposition of organic

[52] https://sentera.com/what-is-ndvi-infographic/
[53] https://pushover.net/

matter. It has been proven in numerous studies that organic farms often contribute to an increase in insect biodiversity[54][55], thus contributing to UN SDG 15[56].

Similarly, to the previous camera cases described above, this system would be as well in need of a solid library of insect types common in the geographic area the farm is situated. Ideally, this library would be set up by professional environmentalists and entomologists (entomology is the scientific study of insects), so that it contains a strong and sufficient enough database for the cameras to work. The cameras would capture the insects at the farm, in different areas and time of day, from different angles, depending on the insect's position, and send these pictures to a software that can run through the uploaded library of pictures and information, in order to identify the photographed insect. This can be done by studying specific characteristic of the insect, such as species, size, colour or behaviour. Once identified, provided it is truthfully identified, the software can send a notification again to interested parties, such as researchers, educators, farm workers, or devotees. Otherwise, if the system is unable to identify the insect, the information (photographic evidence, time of day, location) could be sent to an environmentalist or entomologist to identify the insect.

A possible indicator could be the number of insect species photographed during a set interval or for a specific type of cultivated plant (unit: number; the higher the number, the richer in insect biodiversity the farm is). This indicator can be further investigated and divided, such as the number of invasive species, new and beneficial species, or number of insects belonging to one species. The information provided would be highly useful in the research and education fields, but also in improving and contributing to the organic identity of the farm.

4.1.2 Climate sensors

To get live information, of the crop's quality of life, climate sensors can be placed around the farm. The sensors could send collected data to a corresponding app, where the involved parties would be able to control the data and respond to it. The sensors level of ability to monitor depends on several factors, where outdoor farming, compared to indoor farming, requires a higher level of monitoring and flexible nutrient supply. There are several options for monitoring systems that urban farming could benefit from. As a concept of urban farming AeroFarm technologies uses the following systems to monitor the plants life quality and make their food production efficient:

- ❏ **Smart Light** which monitors and changes the LED lights according to the needs of the plants. This however, is only relevant for indoor farming.
- ❏ **Smart Nutrition** which constantly monitors the nutrients in the soil, and thereby enables the farmer to give the plants exactly what they need. This makes it possible to grow plants in half the time compared to traditional agriculture.
- ❏ **Smart Data** that, through monitoring the plants, extracts data which gives the opportunity to review, test and improve the farming system. A remote monitoring and control solution will be presented in 4.2.1.

[54] Bengtsson, J., Ahnström, J., et al. "The effects of organic agriculture on biodiversity and abundance: a meta-analysis" (2005) 42: 261-269.
[55] Mone, Shamika, K M, Kusha et al. "Comparison of insect biodiversity between organic and conventional plantations in Kodagu, Karnataka, India" (2014) 6186-6194.
[56] https://www.fibl.org/en/themes/biodiversity.html

- **Smart Pest Management** which is part of the growing process and is to be developed to minimize and mitigate pest proliferation. AeroFarm for example, uses controlled indoor climate and growing methods which disrupt the normal life cycle of pests.

In addition to the AeroFarm technologies other sensors could be implemented to monitor the conditions of the plants. A smart watering system could be developed by using sensors that monitor the moist in the soil and then water it as needed. There is a similar system in the AeroFarm technologies, but their system is developed for plants that grow in moist air. A smart watering system would prevent overwatering, and thereby prevent slow growing crops and the overuse of resources. Another sensor that the farmers could benefit from is a sensor that measures the temperature within the soil, in order to know if the temperature is appropriate for the crops to grow. In many countries it would be relatively impossible to grow most plants year round. To make the growing season longer for the crops, infrared heating ribbons could be used to heat up the soil around the crop to prevent them from getting chill shocks. Heating Solutions International (HSI) has made such a heating system that distinguish themselves by only delivering heat in specific locations when required[57], which can be used both in greenhouses and open fields. In enclosed green houses, CO_2 and Oxygen monitoring would be necessary for an effective growth, as an automatic system would be able to turn ventilation on and off as needed, or open the windows on less advanced systems.

4.2 Smart platforms

In order to be able to use the data gained from the smart technologies, especially from the sensors and the cameras, it is important to provide a platform. A Farming App provides the processed and analysed data and contains information about the necessary actions in order to maintain and control the farm. In addition to that, a smart platform could contain more features such as a food sharing app and biodiversity dictionary which will be explained and presented in the further course of this chapter. All these features will contribute again to achieve the defined sustainability targets from chapter 3.2.

4.2.1 Farming app

As mentioned above, urban farming and in particular the smart technologies such as the cameras and the sensors, are creating a lot of useful data which can be analyzed automatically and communicated to the responsible farmer. In chapter 3.1.3, several trends of high potential smart solutions have been introduced, mainly developed for high-tech indoor farms in order to improve the efficiency and outcome of farming processes. The purpose of this chapter is to apply the technology and knowledge of these solutions to an urban farm, which is open to the public, thus contributes to all the targets presented in chapter 3.2. Therefore, the most suitable type of an urban farm for this case is an outdoor farm with either soil-based horizontal farming (see chapter 3.1.1) or hydroponic-based vertical farming (see ZipFarm, chapter 3.1.2). A combination of both systems is also possible, enabling a better area efficiency. To ensure not only the creation of a large amount of data, but also its usability, a smart farming app will be developed. It acts as the user interface translating the data into user-friendly information and suggests or even automatically executes different activities based on the data, created by multiple smart sensors.

[57] http://hsi-heating.com/agriculture/

The farmer can download the app onto any smart device such as a phone or a tablet. Using the analysed data from the sensors and cameras can drastically optimize the growing process which then leads to a higher food quality and quantity. Having an app, similar to the app, introduced in chapter 3.1.3, enables to open the farm to any potential customer, no matter if they are experienced farmers or amateurs. Furthermore, the app allows to create user accounts where people can become members of the farm. All members of the urban farm such as responsible farmers or volunteers working on the farm can get access to the app (register and log-in).

Firstly the farming app provides a database including all kinds of vegetables and fruits, suitable for growing in the urban farm. Based on this database, a holistic farming schedule is created which covers the entire process starting from planting the seeds until the harvesting period. This schedule contains a smart technology which plans different crop mixes for each season in order for the soil to keep in good condition. Secondly, within one season, the schedule is a tool that monitors the daily progress of the growing process and provides the farmers with necessary information and tasks that have to be taken care of. The person who logs in automatically gets a notification on what jobs are required at the respective day and time. These jobs could include watering, fertilizing or feeding the plants with nutrients but cutting plants or composting can also be necessary.

A further digital development of the smart urban farm could be that even the watering and fertilizing is done automatically in a closed-loop system.[58] This enables the implementation of an “I’m busy”-function in the app. Farmers can use this function to communicate their unavailability for the required tasks. If no farmer is able to take care of the farm, the farm would take care of itself with only the responsible supervisor remotely monitoring and controlling the process. Thus, a major problem of existing urban community farms can be avoided. Most community farms disappear or become abandoned because the initial hype will level off after some time and people barely feel responsible anymore. Furthermore, the idea of having an account system and a smart technology creates a sustainable approach that ensures both the integration and accountability of the community as well as a functioning and efficient urban farm.

A practical scenario can happen as follows. The smart camera identifies pests on a plant, as described earlier, and shares this information with all members via the app. In case of an emergency such as louse infestation, the app is able to immediately tell a member of the farm who is online at present and suggests actions in order to save the affected or the surrounding plants. If no member is online or everyone is too busy with other emergencies, the farm activates its back door and uses an automated and predefined solution process for the specific pest. This demonstrates again the increase in efficiency the farming app can provide, because immediate action can avoid serious consequences.

The farming app does not only optimize the food production but it can also be a tool to develop a community. A possible feature of the farming app could be a vote where people can chose what vegetables, fruits or herbs they want to grow or consume. The participation in votes like this or in other events (such as bringing compost to the farm) could be awarded by gaining points. Points then lead to higher ranked votes in the seasonal elections of the plant environment. This leads to a higher participation and motivation by providing clear incentives

[58] Interview Seasony (see appendix 2)

for the members. In consideration of all these features of the app, a possible layout has been developed and is provided below in Figure 8:

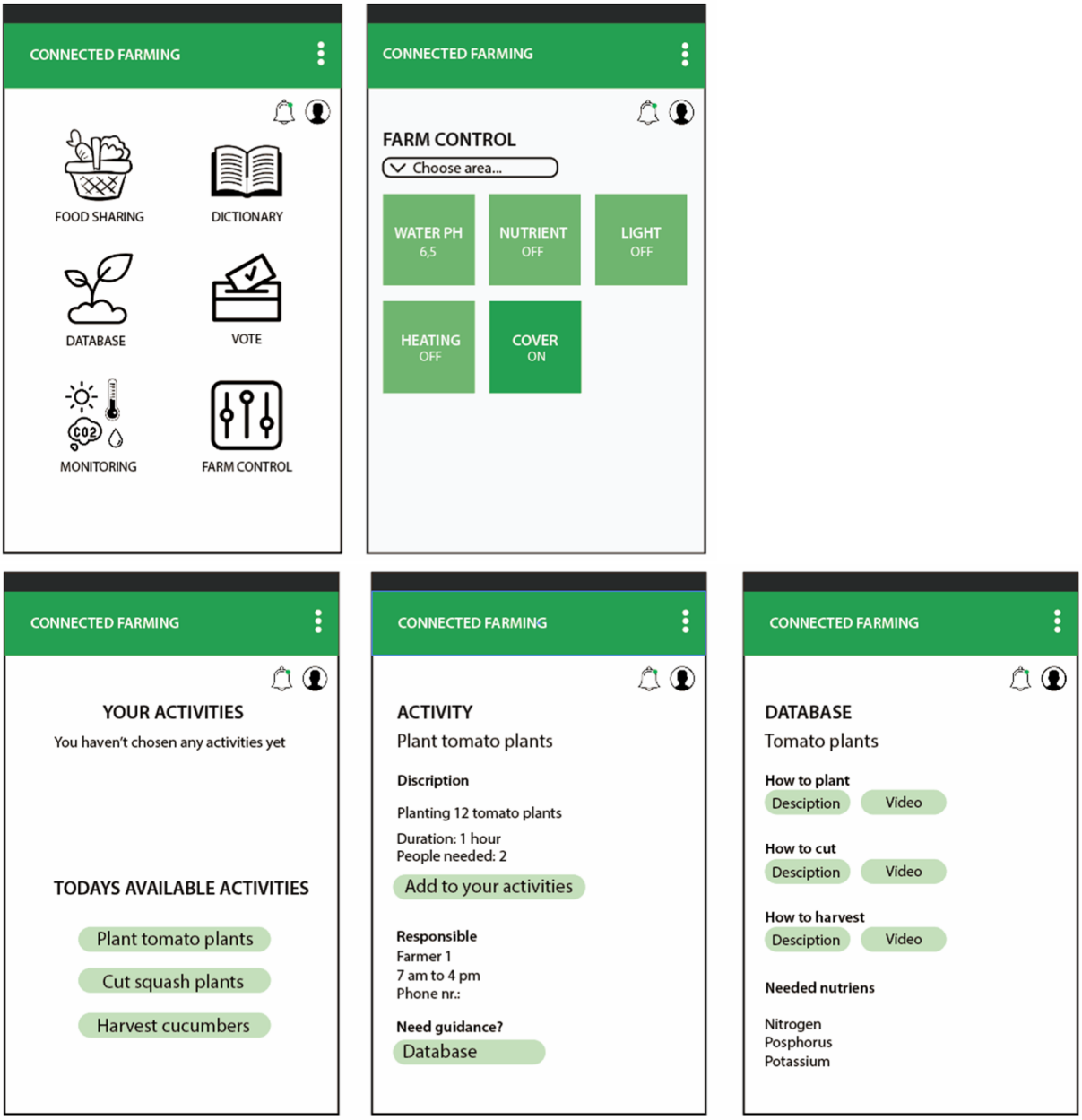

Figure 8: Smart farming app interface

4.2.2 Food sharing app

As part of the smart platform, a food sharing app could be implemented. It is similar in concept to apps already available on the market, such as Olio[59] and Too Good To Go[60]. However, our solution would be highly customizable to local government's wishes and needs, and it would be part of cities' smart solutions. The main users of this app would be citizens (already volunteers in the urban farming scheme or not) and restaurants interested in buying organic and locally sourced food. The app would be developed by software specialists and

[59] https://olioex.com
[60] https://toogoodtogo.dk/da

programmers. The customers would have an option to log-in with a personal ID (possible identification number already of the healthcare system or local and national governance) and have access to their account, where they can see information such as their purchases, nearby farms or the food variety available for purchase. The volunteers working on the farm would have an already included discount. The app would display the amount and the type of available food per urban farm, with the users having the options to choose how much of produce they desire. Online payment options would be available as well, and, once the order is approved, the produce would be available for pick-up at the originating urban farm. In terms of technological requirements, it would be similar to any other app that is part of the app stores on mobile devices. It would require storage on customers' phones (approximately 75-100 MB) and it would use customers' mobile data (3G, 4G, 5G, Wi-Fi connection).

Possible indicators for this technology would be the amount of food sold to volunteering customers, regular customers, restaurants, and possibly out of the total produced food (unit: number; the higher the number, the more efficient the farm is in terms of output and more food has been used).

The security implications this smart technology would have have to be considered. Generally, the IoT is susceptible and vulnerable to software attacks by hackers. If broken into, the system can expose sensible data and information from the users and the farms alike. Personal data, passwords, emails and login information, linked accounts (such as bank and social media) can be exposed and used in fraudulent ways. Furthermore, input from cameras and farms can be manipulated, falsified, or deleted. This can impact the farm as well, putting the harvest and the collected information in danger. In order to protect from this risk, the system should be equipped with a data protection software from specialized distributors or companies. A secure software can keep the protection system updated and be connected to serve with enriched security measures.

4.2.3 Biodiversity dictionary

Another possible smart technology would be an app designed to identify the type or species of plants and insects living at the urban farms. The main end-users of this app would be local school students and their educators, but also regular citizens interested in the biodiversity of their cities.

The technology an app like this would use is similar to the technology already in use at the cameras. However, the technology would need to be adapted and scaled for mobile usage. The output would also be customized, so that the end-users are getting captivating and interesting information about the organism they just photographed. Links, images, curiosities, and facts would be sent to the users once the plant or insect was identified. Furthermore, to amplify the role of the app and in order to work for the sub-targets of UN SDG 15, the app would inform about the role of the plant or insect in the local ecosystem, thus providing education about biodiversity. Since the app would be available to use remotely (not only at urban farms), it encourages the usage in nature or throughout the city, increasing the biodiversity awareness.

A possible indicator would be the number of identified species and how many of them have been looked into by the users (unit: number; the higher the number, the bigger the success the app has). This information would be useful to educators and schools, in order to adapt their curriculum, but also to municipalities and local government to research on their citizens engagement.

5 Smart urban farming solution: A business model

Urban farming is not a new concept. It has been around in the current form for a couple of decades, even though in the recent years it significantly gained in popularity and many urban farms were implemented on different scales with different purposes in dense urban areas worldwide. However, as technology advances, it is important to incorporate it into the everyday life, thus into urban farms as well. The technological solutions mentioned in chapter 4.1, as well as the smart platforms (chapter 4.2), are high potential developments that could increase the overall performance, the efficiency, but also the acceptability and the use of urban farms for communities.

The goal is to create a smart urban farm based on the mentioned IoT solutions. Firstly, the parties and partners responsible have to decide on a design, purpose and functionality of the smart urban farm; a physical location for the farm is also needed which can for instance be a rooftop. Furthermore, several decisions considering the structure of the planting have to be made. In this case, the optimal solution would be to include a greenhouse (indoor farming), horizontal outdoor farming patches as well as vertical farming possibilities in order to use the space as efficient as possible. The farming app, with its various features, is the essential tool to maintain the smart urban farm. As mentioned in chapter 4.2.1, it controls the growing process, considerably automating the farming. However, it is supported by farmers working full-time on the farm as well as by volunteers who can each have different roles and responsibilities. The farm would function with a closed water circuit solution, where plants extract the necessary nutrients from a mixed solution of water and organic fertilizers. Fresh water is only supplied when the water drops below a certain level.[61]

Because most of the farming is done automatically, it is important to still be able to participate in the smart urban farm. According to the urban farming start-up Seasony[62], which was invented a year ago in collaboration with DTU, the social aspect of smart urban farming is very important to consider.[63] By providing several opportunities mentioned in chapter 4.2.1, such as a vote for preferences in the growth of certain vegetables or a scoring system for several actions, the participation of the community can be increased. The food sharing app of the smart urban farm is another feature which not only contributes to an increase in sustainability but it also strengthens the interaction of the community.

More green spaces have a positive impact on the life quality of people. Providing public access to the farm could increase the acceptability of a smart urban farm, thus contribute to a better relationship between different groups of people in a neighbourhood.[64] Moreover, it could educate visitors about agriculture and food production and it can increase their awareness of food, its origin and quality. Our solution stresses the importance of education and how to make education accessible and interactive. The biodiversity dictionary app brings the nature world into the hands of people, and on the farm these people could learn more about the food and the plants growing there from employees, researches, or from each other.

[61] Interview Seasony, 18.10.2018
[62] https://www.seasony.dk/
[63] Interview Seasony, 18.10.2018
[64] Interview Seasony, 18.10.2018

A proposal how an urban farm could look and work like is presented in Figure 9 below. It details not only the connections between the smart urban farm and its technologies but also between smart urban farm and its users.

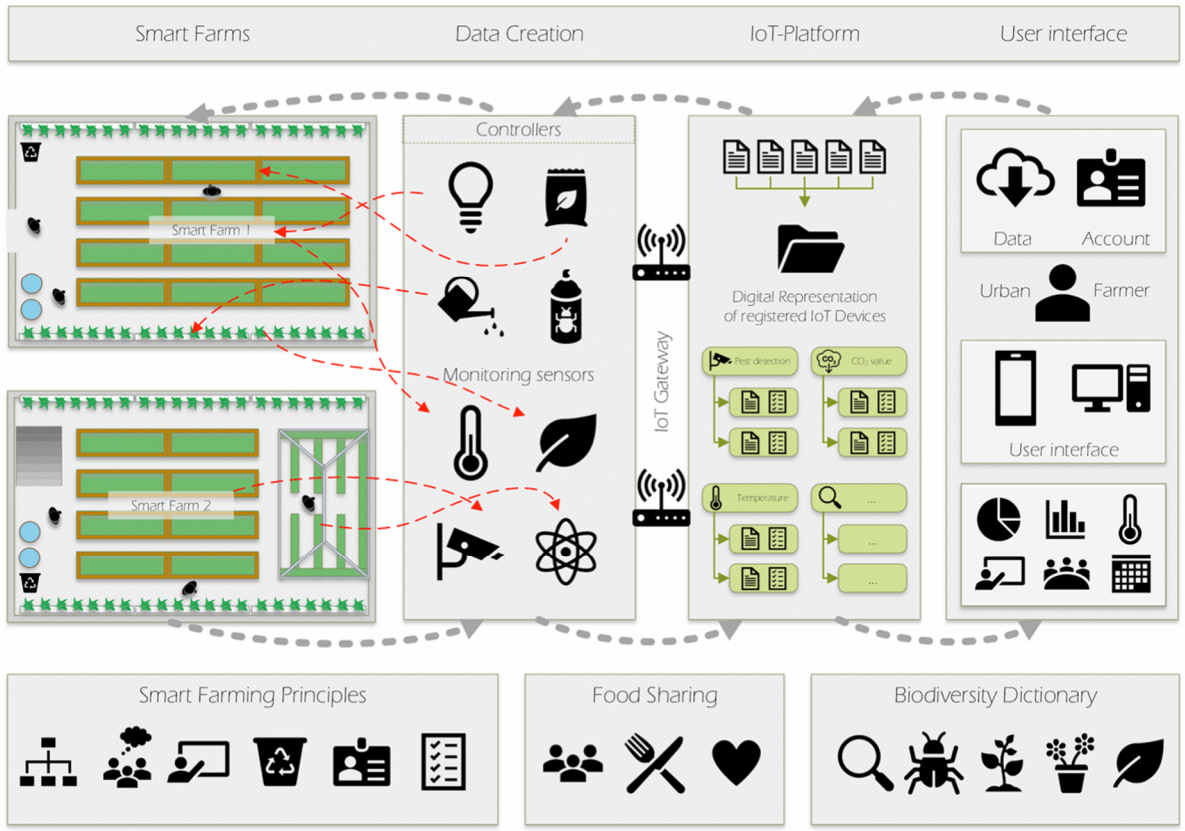

Figure 9: Design of the smart farming solution based on IoT systems

It is however essential to examine a model with its implementations and technological solutions as explained above, in order to check the feasibility of our ideas. By developing a business plan, we discussed various issues and came up with the results as follows:

Business model canvas:

Key partnerships:	Municipality
Key activities:	Communicate data from sensors
Key resources:	Experts (knowledge on how to use the app and interpret the data) & sensors/technology.
Value proposition:	Performance. Making agriculture more efficient/better.
Customer relationship:	Personal assistance. Work with customers to improve the data collection and communication.
Channels:	Direct sale, sales force/web sales. How do we make the municipalities aware of this product.
Customer segment:	Mass market. Needs to be applicable for all cities/urban areas.
Cost:	Value-driven (focus on value creation) / variable costs (vary proportionally with the volume of goods or services produced

Revenue stream: Subscription fee/renting/licensing? Do they pay a monthly fee or is it a one time sale? Asset sale. Pay to get the personal assistance.

For our smart farming solutions (smart IoT technologies, smart platforms) we identified the municipality as a key partner in implementing a smart urban farm as described above. As a key activity, it was decided to focus on the communication of the collected and analysed data from the sensors to the smart platforms, especially the smart farming app. Experts on the sensors and technology would be able to program the app and interpret the data so that the end user (farmer, volunteer) could operate it easily. Our value proposition is to optimize the farming, hence the focus lies on the performance of the farm. Another important aspect of the business plan is the customer relationship which in this case is described as the personal assistance, meaning that the employees work with the customers to constantly improve and optimize the data collection and the communication. The goal is to distribute the smart urban farming solutions via direct sale and web based sales. Furthermore, the solution is mass market oriented; it is essential that the technologies and smart platforms can be implemented and adapted in smart urban farms in every city over the world. It has to be noted however, that the basic conditions differ for each city or urban area, therefore the smart farming solutions will not be implemented to the same extent or in the same way. That is why a value driven cost model, depending on the volume of goods or services produced, is the basis for the cost calculation for the product. The revenue streams for the IoT solutions can be divided into to parts, as the app can be sold as an asset sale, a one time payout or a subscription fee can be paid every month for the usage. Another revenue stream could be pay for consulting hours, as consultants could provide assistance in analysing the monitored data collected by the app.

When considering the Copenhagen based urban farm Østergro[65] in relation to our idea of a smart urban farm, it becomes clear that the farm has a high potential to turn into a smart urban farm with the features explained above. The location as well as the structure of the urban farm is similar to our goal and could be complemented with some vertical farming patches on each side. The already existing greenhouse acts like a restaurant at present which indicates the focus on the social aspect on østergro. The responsibles could include some farming into the greenhouse in order to be able to grow more sensible food as well. Implementing the farming app as well as the dictionary would definitely be possible in that project as well, and in our perspective it would add considerable value to the farm itself.

Further developments in smart urban farming could however include the interconnectivity between different farms as presented in 3.1.3, to develop a broad expert knowledge base with data from different urban farms around the world. The smart platform with its various features could benefit from that and so could the users. By connecting different smart urban farms, the data collection and analysis is steadily enlarged. That has a positive impact on the educational aspect as the plant species and the needs of the respective plants would be included in the dictionary and people could learn about that.

Different farming techniques and approaches towards different plant types can contribute to a sharing and helpful society in the agricultural sector which can then optimize the farming even more. Sharing expert knowledge with farmers from different cultures and climate zones could furthermore help to avoid illnesses and other problems concerning the plants and the crops.

[65] http://oestergro.dk/

Not only has the connectivity positive impacts on the farming itself, but it can strengthen the bond of farmers and therefore contribute to the development of a network of farmers worldwide. Additionally, the smart platform which is interconnected could act as a platform on which different people who participate in the smart urban farm can exchange ideas with each other, not only learning more about agriculture, but also establishing social contacts worldwide.

6 Reflection

Our solution does not propose to completely eradicate the problems of our world. Hunger is present in every society, biodiversity levels are alarmingly dropping all over the world, and population groups can be extremely polarized in their ideas, values and goals in relation to urban farming. Our solution means to help in solving these problems. Our proposal carefully considers the goals under UN SDG 15, and comes up with smart urban farming as a frontrunner in addressing these issues in an appropriate, viable and, most importantly, accessible way.

Smart urban farming can increase the biodiversity levels of an area, not only by contributing to the likeliness of cultivating or protecting less common or endangered species of plants, but it can lend a hand to local insect population. It can offer a refuge for local species, and can introduce new, harmless ones in such a way that it can and should only be advantageous to its surroundings. This can be controlled with our proposed smart solutions. Smart urban farming will not resolve hunger and famine, but it can help alleviate issues and deploy solutions in affected communities. It can have its limitations (physical space; limited financial possibilities; population reticence to traditionally-challenging ideas), but, if deployed carefully and backed with heavy research and understanding of the target public, client or users, it can greatly benefit its environment.

In our opinion, the capital necessary to start such an business or make our solution reality can become the biggest obstacle. It requires a great deal of cooperation across multiple areas from all the involved parties (municipalities; farming and environment specialists; end-users; farm workers). This can be further explored and understood in depth with help from the business case in chapter 5. Furthermore, it could be argued that a smart urban farming solution, together with its entire concept of smart technologies, proposed smart platform, and user relationship, does not meet the targets under UN SDG 15 - Life on land and its sub-targets of biodiversity protection; an argument in that regard could be that our proposed urban farming ideas are related in a higher degree to cities, which are not entire synonym to biodiversity. However, since most of the world population lives and will live in cities and the role cities play on the world stage, often acting as engines and affectors, it is adamant that urban communities work as efficiently as possible. We consider that our smart urban farming solution needs to be considered together with its background, its possible impact, as well as with the purpose and intentions set in chapters 4.1 and 4.2, urban farms can contribute to achieving the targets under UN SDG 15.

7 Conclusion

The present paper is intended to address the implications of a smart urban farming solution that works with and towards the UN SDG 15: Life on Land. The smart technologies have been thoroughly researched and proved that they can work in real life, scaled and dimensioned for their field of applicability. We believe that the report makes a strong case for the implementation of smart urban farming solutions in cities, to settle down to biodiversity levels, food production, climate change, and socio-economic elements. As mentioned before, the proposal does not mean to fully solve the problems described above, but it is meant to provide ways and understanding in solving these problems.

Smart urban farming can seem like a strange idea at first. But the present report considers it to be absolutely required in a fast-paced society like ours, and a society that is facing the inevitable problems and obstacles to come. Our smart urban farming proposition means to deploy technology for the benefit of the users and of the environment, to make urban farms a friendly and accessible project, to protect and work for its location, with and for the people. Overall, it aims to contribute to an increased quality of life, and a bold and bright vision of the future set in the present times.

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