REINTERPRETING THE FARM - A VIABLE COUNTRYSIDE

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ABSTRACT

In the agricultural sector farming methods and upscaling of farmland are problematic for biodiversity and survival of farm businesses. Not all farmers can compete on the large scale, so the farmer has to find other ways of adding value to their product or business. One of the methods that will be used for that is the Material Flow Analysis to analyze a farm's outputs, for this a farmer was contacted to conduct a case study. A combination of production and landscaping measures can balance the scale towards a more viable countryside with positive ecological impact. This results in lower-intensity farming businesses that are not yet economically viable, to achieve this cooperation is essential and support from society must be enhanced.

KEYWORDS: *agriculture, landscape, material flow, Limburg, sustainable farming*

I. INTRODUCTION

Recently, our agricultural sector has been the subject of discussion. The use our land in the future, with population increase and biodiversity decline? Focusing on an agricultural area in the Netherlands, Parkstad Limburg, I hope to suggest a new way of dealing with the relationship of humans with nature, agriculture and urbanization. The project will rethink the farm which can no longer retain its original function, especially in Limburg. Therefore, agriculture needs to be considered in the context of production processes and waste flows in order to find new programme. The aim is to provide redesign proposals for a farmhouse and its surrounding agricultural land. The thematic research will therefore focus on the main research question:

- *How does analysis and optimization of material flows increase the potential of a new way to deal with our land and create new programme for farmhouses in Parkstad,Limburg?*

Sub-questions:
- *What is the current situation of the waste and production flows of a farm in Parkstad Limburg?*
- *Which material flow or treatment can be added to a farm to make the production processes more circular?*
- *Which material flow can lead to new programme to strengthen the position of the primary producer, the farmer, in Parkstad?*

First, an analysis of production and waste flows is done through a case study. Secondly, different landscape elements are discussed and finally the possibilities of adding programme to a farm.
The goal of this research is to find solutions to the problems of the segregation of urban and rural, mass production and the problem of monoculture of the landscape that is operational to our consumer society. Then find a way to close the local metabolism of flows (crops, waste etc.) and include supporting programme. This will result in a viable countryside for both humans and non-humans.

II. PROBLEM STATEMENT

In the agricultural sector our farming methods and upscaling of farmland are problematic for biodiversity. On the one hand our countryside is very much focused on production, on the other hand there is a growing lobby to preserve what is left of our ecosystems and unique cultural/landscape heritage. But the production usually seems to prevail anyway (Havermans, 2021). Large-scale farming and intensification of farming practices (monocropping) lead to ecological monoculture; a single crop and fertilization lead to less diverse belowground resources and eventually to impoverished soil, which in the end puts agriculture at a disadvantage. Recent studies have shown a strong decline in both insect, biomass and species diversity with a potential cause in agricultural intensification, as a consequence of increased inputs of nutrients and pesticides (Tittonell et al, 2020). In Limburg the number of farms in operation together with employees declined since the ’60 following the national trend (Appendix figure 1.1) (Centraal Bureau voor de Statistiek, 2021). Consequently, farming businesses scaled up with an average of 20 ha to 34 ha per estate between 2000 and 2020 and becoming big producers (CBS, PBL, RIVM, WUR, 2021). In Limburg high production at a low cost (per unit product) is becoming less of a crucial advantage in competition with other producers. Because of high cost of labor, cost of land and costs as result of amended policy, the business model with high production is only viable to a few largescale producers.

The farmer has to find other ways of adding value to their product or business as they are not all able to produce on large scale. An additional issue is the weak position of the primary producer, the farmer, in the supply chain. The challenge, therefore, is to strengthen the position of the primary producer, as recognized in the national agricultural policy. But not all entrepreneurs in the agricultural sector have the ability to innovate, but all will inevitably be faced with the transition to circular production in the future. By building on existing farming concepts this can happen efficiently. The Province of Limburg is supportive towards the national policy objective of achieving circular agriculture for the region. Circularity can be approached at several levels; the cycle can be explored at the level of the agri-food sector, the cycle can be sought the level of the farm, in cooperation with local businesses, but also, for example, on a larger (inter-)national scale (Provincie Limburg, n.d.). This research will focus on the level of the farm.

Due to the global market on agriculture, only large-scale producers can compete. A new incentive is needed for the small-scale farmer to avoid bankruptcy and losing an important part of our rural culture. Therefore, our ways of farming need to be revised and so does the function of our program of contemporary farmhouses. Agriculture takes place on the large scale because the market does not demand local production, but mass production. Mass production in agriculture ignores the local scales of production and affects the way the landscape is shaped. Also not having a local market blurs our consciousness of knowing where food (and more) is coming from; causing a disconnection between human and nature.

In contrast to many other areas in the Netherlands, agriculture in Heuvelland (the southern part of Limburg including parts of Parkstad) seems to be largely focused on broadening of business and less on intensification or scaling-up. The area is promising for the development of multifunctional agriculture and 'broadened' rural development. In fact, in the area of South-Limburg the share of multifunctional farms is above national average (Appendix figure 1.2). This offers opportunities to improve the quality of the landscape (Agricola, Hoefs , Doorn, Smidt, van Os, 2010) I see this as a launching pad for development of a more small-scale, circular farmhouse. Despite less intensification on regional level, the populations of indicator species tell us that the ecosystem is deteriorating: in Parkstad especially the farmland species are declining rapidly (Provincie Limburg, 2017). So in addition to rethinking land-use to keep the farmer in business, we also need to rethink the landscape in terms of ecology.

III. RELEVANCE

Runhaar (2017) says that we need to produce more knowledge about how agriculture can be made more nature-inclusive and at the same time support the farmer's business, because in contemporary discourse the farmer is often held responsible for the degradation of the landscape (Tittonell et al, 2020). It is also important to think about the future of the farm and the landscape. Both will not remain the same and in Limburg specifically, the question of the meaning of the countryside is relevant in relation to the issues that exist there.
The feasibility of investment towards new, in this case small-scale, ways of farming is to be considered. Food production on a large scale is beneficial to sustain increasing numbers of inhabitants. The small-scale solution may not be effective. It may be an effective measure for preserving ecology, but the measures that are the most effective from an ecological point of view are also those that are the most challenging to integrate into agricultural production (Runhaar 2017). And a controversial point about transitions to, for example, smaller scale farming is the need of more labor requirements. Hiring new employees is a high cost for farmers, but perhaps creating employment can also be an opportunity to bring people back to the countryside (Tittonell et al., 2020).

IV. RESEARCH FRAMEWORK

4.1. Methods

The goal of this research is to form a foundation and find solutions to the problem of monoculture of landscapes and mass production, to find a way to add programme and close the local cycle of flows (crops, waste etc.) and adding or optimizing programme to diversify the surrounding land and create chances for farmers to broaden their field and stay in business. One of the methods for analyzing flows that will be used is the Material Flow Analysis (MFA). MFA is a suitable tool for researching towards optimization of a farm; Allesch and Brunner (2015) state: "*MFA on the substance level is a key tool for decision making in view of the goals protection of humans and the environment, conservation of resources, and aftercare-free waste management.*" In order to make an informed suggestion, regarding the optimization of a material flows and possible new program for a farm, a case study was conducted. By mapping the yield and distribution of a farm, it is possible to develop a new concept, both economically and spatially, to make a statement about the future of the farmer. The expectation is that this approach can shed a new light on the countryside and regain a sustainable balance between economic benefits and sustainable values (Appendix figure 3.1).

During the visit to the region, several people were interviewed about the local agricultural sector, including farmers. A farmer was contacted to participate in a case study. This farmer, Mr. A., was willing to release his data on crop production, use of pesticides, water and waste flow. Secondly, these data were processed in a Sankey diagram (Appendix figure 5.1) to gain insight into incoming and outgoing material flows. Based on the information, calculations were made to determine what the yield and the possibilities of residual flow applications. In conclusion, alternative methods of farming leading to a new programme both on the farm and in the field were considered.

4.1. The Case study: *Onderste Hof*

Parkstad is a relatively hilly city region encompassing the municipalities of Heerlen, Landgraaf, Kerkrade, Simpelveld, Brunssum, Voerendaal and Beekdaelen. With a population of 256,000, it is largely urbanized and touches the border with Germany on the south and east sides, while on the west side, the rural municipality of Voerendaal runs into the Heuvelland and the Geul Valley. On the north side, there is also a rural municipality: Beekdaelen. The other municipalities are mostly urban. So there is a challenge to find the connection between the urban and the non-urban; this can be a valuable addition to the urban area. By adding value, which is present in the countryside in the form of monumental farms and old landscape structures, a stronger identity can be created in the region.
The farmstead being analyzed is located in the municipality of Brunssum (Appendix figure 4.1) and is called the *Onderste Hof*. The owner, A., owns 47 ha of arable land. This case is special because A. is at the center of the current regional agricultural issues of Parkstad. He has had to deal with the pressure

from the banks who are committed to intensification and expansion, but on the other hand, the new government measures for sustainability. A. is already working on making his farm and the methods he uses to farm the land more sustainable. It must be emphasized that this is a case study that does not correspond to the vast majority of farms. The case study deals with a farmer who shows willingness to make sustainable changes to his farm.

V. RESULTS: CASE STUDY *ONDERSTE HOF*

5.1. Yield of a farm in Parkstad, Limburg

A.'s farmland covers 47 hectares. The main crop is potatoes, but to keep them growing, crops have to be rotated. The land can grow potatoes once every five years. In the other years, maize, barley, wheat, sugar beet and radish are grown. The latter is a green manure crop and is ploughed into the soil to add nutrients. In this paragraph, a calculation has been made of the crop- and waste production of the *Onderste Hof* per crop (Appendix figure 5.1 and figure 4.1, 4.2). The most recent national averages of the 2021 harvest estimate of Centraal Bureau van Statistiek have been used. In reality, yields are subject to multiple factors. These are not all considered in this study.

Potatoes: In 2021, 7.73 hectares of A.'s arable land was used to grow potatoes (Appendix A). The yield of the potato harvest is, according to the national average, 49 tons per hectare this year. The yields are therefore the same as last year. This means for the 7.73 hectares of arable land a gross yield of 49*7.73 = 380 ton of potatoes. The potatoes are turned into French fries on the farm and distributed at the local market (Centraal Bureau voor de Statistiek, 2021). In some years, potatoes remain too small to make fries and are sold to Aviko.

Sugar beet: 11,96 hectares of farmland was used to grow sugar beets. With an average yield of 81 tons per hectare, this results in 11,96*81 = 970 tons harvest (Centraal Bureau voor de Statistiek, 2021). The buyer of the beets is Cosun, a company that uses the beet as a whole for a wide variety of purposes.

Wheat and barley: 16,85 hectares of winter wheat was grown. In 2021, barley was not grown, but was used in other years. The yield of winter wheat per hectare was 8,7 tons (Centraal Bureau voor de Statistiek, 2021), this results in 8,7*16,85 = 147 tons of wheat. The harvest was delayed by a long period of inconsistent weather in August resulting in a moderate yield in the Netherlands. Yields of 10 tons per hectare are normally easily achieved, but this year was an exception (Agrifirm, 2021). The buyer of the wheat is Agrifirm. Most of the wheat grown on Dutch soil is unsuitable for the production of flour and is used as cattle feed.

Maize: 10.06 hectares of farmland was used to grow maize. The maize is used as silage to feed livestock, this means that the plant as a whole is shredded and sold to local cattle farmers, with no residual flows. The plant as a whole delivers 42 tons of silage per hectare, for the *Onderste Hof* this adds up to 10.06*42 = 423 tons (Centraal Bureau voor de Statistiek, 2021).

5.2. Residual flows and their potential

Residual streams that are currently a cost item for farmers can potentially be of value. In the context of global material scarcity reusing waste can have positive effects on the climate. Possible purposes of waste are among others natural fibers, fermentable sugars, glues, biodegradable plastics and ingredients for pharmaceutical products and human nutrition (WUR, n.d.). For the crops, grown in 2021 at the *Onderste Hof*, an overview was made of the possibilities of using residuals.

Potatoes: waste streams in the case of potatoes are normally negligible, the leaves and stems (about 3,1 tons per hectare)(Janssens & Smit, 2016) are left on the land, but making French fries on the farm, like the *Onderste Hof*, creates peeling waste. This waste is transported to a local farmer and fed to livestock. On industrial scale the management of peels is more relevant. Potato peels are a source of dietary fiber (the quantity depends on the peeling method). Apart from being processed consumables, the peels can be used for animal feed. It can also be used for fertilizer. There have also been experiments to produce acetone, butanol and ethanol by fermentation of the peels (Locker, 2021). The waste water from processing potatoes consists of high amounts of nitrogen and phosphorus, important nutrients for crop

cultivation. Potentially processing waste water can replace artificial fertilizer and reduce pollution of farmland. The share of peels of harvested potatoes varies from roughly 12,5-15,0% of its weight, this relies on the soil type. (Locker, 2021) the *Onderste Hof* that would add up to approximately (380*0,125 + 380*0.15)/2 = 52 tons of potato peels. The leaves and stems, 7,73*3,1= 24 tons, are not suitable for feeding livestock, only as fertilizer or potentially as input for bioplastics (Janssens & Smit, 2016).

Sugar beet: Residues of sugar beets are usually left on the land, but hardly contribute to re-fertilization of the land. But the rotting process the leaves release a lot of CO_2 and valuable nitrogen and phosphates are washed into the ground (WUR, n.d.). Waste from sugar beet is not lucrative outside industrial processing. Although research has shown that the leaves are composed of materials that are interesting for chemical and biotechnological industries. Potentially low-cost waste of the leaves can be turned in valuable chemicals or yeast biomass (Modelska et al, 2017). Research has shown that extracted proteins can be used in a profitable way to make food products, such as meat substitutes. (WUR, n.d.) Per hectare sugar beet about 20 ton of leaves are produced ('T Hoog, 2020). For the *Onderste Hof* this adds up to 11,96*20 = 240 tons of leaves.

Wheat and barley: the amount of straw naturally depends on the weather, the equipment used for harvesting, the grain variety and the type of soil. But on average about 4 tons of straw is produced per hectare. (Kennisakker, 2020) This is equal to 200 straw-bales of 20kg. Straw is not actually waste, but a sustainable and versatile material; it is used for different purposes such as feeding livestock, fertilizer, insulation and construction. The straw is often shredded and used in stables or as litter for the land. The question is whether these applications really use the potential of the material. The farmland of the *Onderste Hof* produces 67 tons of straw.

Maize: the maize that is grown for animal feed has no residual waste flow. The whole plant is used as silage.

5.3. Small-scale waste processing

Bioethanol production of peels and leaves would demand a regional approach. By linking up different farms and collect their residuals it could be possible. Companies in bioethanol production such as Alco Biofuel take thousands of hectares of crops. Other products from for example sugar beet leaves are not economically viable, because of the low value of the output (De Visser & Van Ree, 2016). Small-scale biorefineries and bioreactors are being developed and could be a solution in processing waste locally, but those are still their early stage. The biorefinery GLAS has developed a mobile biorefinery that splits grass in four products that can be used for different purposes and decrease the phosphate and nitrogen deposition. Biogas can also be made from waste on the small-scale, but these bioreactors are often made for waste processing not for gas production. Although ENKI-energy developed a bioreactor for the larger scale that that runs on at 2m3 to 200m3 of green or food waste per week which equals about 0,75 to 75 tons. The produced gas can be used locally. The residuals of refineries and reactors are clean water a small amount of waste (Bruins, Togtema, Meesters, 2014). It is also possible to use corn, grains, hemp and sugar beets to produce biogas.

5.4. Conclusion on residual flows and their potential

Looking at the current distribution of the harvest, the system of French fries production is the most localized. Farmer A. himself keeps in touch with customers and does the transportation, activities that the normal farmer does not do, but which have brought about the preservation of the *Onderste Hof*. The other crops are processed and transported through a national or regional intermediary, which means more transport, but also more possibilities in the efficiency of using residuals. On the farm scale, there are interventions possible to generate energy, but they still require knowledge and investment that farmers usually do not have.

VI. RESULTS: SUSTAINABLE LAND USE

6.1. Sustainable land use

There are several interventions that can be done to counteract monoculture on cropland and preserve ecology: adding landscape elements, carefully select crops and combinations of crops. A combination of these interventions leads to a more diverse and natural way of using farmland and can create new economic incentive for farmers. Exploratory research in the area of carbon dioxide storage on farmland is currently being conducted. Combined with a revenue model for farmers, it could be an argument for planting more crops with a greater biomass, hedges and trees in the future. This section describes different methods of farming and adding landscape elements (Appendix see figure 6.1, 6.2).

6.2. Ecological farming interventions

Ecological crops: year-round soil cover helps prevent nutrient leaching and erosion. Resting crops that also attract insects can be chosen for this purpose. Diversifying the number of crops contributes to higher biodiversity. Food for farmland birds may also be a criterion for crop selection. Grains and grasses are eaten by more species; crop residues are eaten by finches, buntings, geese and partridges. Corn, on the other hand, is a crop that benefits few species (Dawson, Norén, 2019).

Perennial crops: Beyond the usual crops grown for economic reasons, there are other angles from which to choose a crop. As can be seen at A's farm, there is an annual crop change. There is ploughing, fertilizing, pest control and sowing to be done. Often at the expense of soil life and composition. Many agricultural crops, like in the case study, are grown as annuals. One way to be more sustainable with the land, preserving nutrients and keeping the soil intact, would be to use perennial plants, such as biennial flax (*Linum bienne*). Having crops year-round on the land is means a further developed root system which is a suitable medium to prevent erosion and improve water- and nutritious balances. Both of which present a current problem in Parkstad, Limburg.

The problem of perennial cultivation is that the Dutch way of farming is set up for annual cultivation. in addition to reducing yields, biennial crops do not fit into the farmers' rotation schedule in which there is one year of a dormant crop and then normal crops again. Growing crops two years in a row would be too expensive (Mangnus, 2012).

Polyculture: Besides changing from annual to perennial plants, it is also possible to apply mixed cultivation strategies: polyculture. One of them is the Three Sisters, a Native American technique for growing squash, beans and corn together. The technique has high yields and uses the properties of the different crops to naturally deal with weeds and maintain nutrients in the soil. More common in the Netherlands is strip farming, which is also beneficial to the soil, as different crops maintain soil ecology and therefore bring about a more diverse ecology. There is always a crop remaining which provides cover for small animals, insects, and thus food for farmland birds, for example. This also requires less pesticides because there is no monoculture where parasites can occur en masse. In addition, with some knowledge of crops, polycultures can be designed in which crops benefit from each other (Mt.Pleasant, 2016). A similar method called pixel farming is under development.

(Agro-)Forestry: Agroforestry is a way of integrating fruit-bearing trees into agriculture. The ecological benefits are positive and well substantiated, but there is still little information for large-scale implementation. The effects are similar to those of planting hedges. Agroforestry requires new knowledge and re-training of farmers (Tittonell et al, 2020). Growing a forest could become interesting if there is a subsidy for CO2 storage.

Permaculture: permaculture is a carefully designed and maintained ecosystem which resembles a natural ecosystem, but is agriculturally productive. Within is this ecosystem waste must be recycled to keep the system going. Conservation of diversity is of crop species is embedded in permaculture. Because water management, waste and crops must be considered integrally, the farmer must have good knowledge of these issues (Mollison, 1997).

6.3. Ecological landscape interventions

In addition to carefully choosing crop species, design of the countryside can also mean a lot to agriculture and the farmland's ecology. Some landscape elements can provide water retention, draw nutrients from deeper layers of the soil or attract insects that pollinate. What the landscape looks like can mean a lot to broaden opportunities for the farmer. An attractive countryside where ecology thrives is also more attractive to recreationists. It is important to understand that agriculture, people and nature can co-exist and benefit from each other. In February 2021, the association of Deltaplan Biodiversiteit produced the document "Aanvalsplan Landschapselementen" which argues to have at least 10% of the agricultural area covered by high diversity landscape elements by 2030, by looking at the local identity of the landscapes (Deltaplan Biodiversiteitsherstel, 2021). in Limburg, many hedges have traditionally been used to separate land and difficult areas of land such as slopes were not used for agriculture. In A.'s case, at the time of land consolidation, unworkable land near the Merkelbekerbeek (a nearby small stream) was bought up and has become a natural area. Some proposals for landscaping elements to optimize the farmland's diversity are explained is this paragraph.

Water elements: in intensified landscapes ditches are being mowed and groundwater levels are low. A smoother transition zone between water and land can benefit al kinds of animal species and enhances layers of different vegetation: nature-friendly banks. The same goes for puddles. When well-designed it can also contribute to pest control and water buffering (Dawson, Norén, 2019).

Hedgerow landscape: an age-old principle that has been used worldwide as a yard fence are hedges. Due to land consolidation, the hedge has disappeared as a landscape element. Hedgerows form an important safe haven for biodiversity, better than a flower strip or a cover crop. A British ecologist found as much as 2,070 species in an hedgerow. Their root systems can reach deeper than crops to extract nutrients and enrich soil ecology. Above the ground the diversity of plants attract pollinating insect which are vital for the crops. The hedge can be a solution to nitrogen deposition and binds CO_2. The disadvantage is that the hedges are expensive and require a lot of maintenance. But researchers recently made an estimation that it is possible to save about €3500 over 7 years on pest control by planting a 300m hedgerow (Morandin, Long, Kremen, 2016); hedges attract natural enemies of crop-damaging species (Zimmer, 2021). Woody elements such as groves and rows of trees have similar effects to hedges. Trees can also bear fruit and thus contribute to production; in addition, orchards have an important cultural-historical place in the Limburg landscape.

Weed strips: Field edges can be used for sowing herbaceous plants. Consideration can also be given to attracting specific pollinators that are beneficial to crops. The strips can contribute to connecting natural areas and function as passing zones for wildlife. However, these strips are not attracting both woodland and grassland-dwelling species like hedges (Morandin et al., 2016);

6.4. Conclusion on sustainable land use

It is proven that plant- and animal species benefit from a more diverse landscape. South-Limburg is a sanctuary for threatened species of agricultural areas. A combination of production and ecology can balance the scale towards a more viable countryside. The only problem is that, when farmers want to implement an alternative way of farming, they need support and knowledge to eventually create a successful business model (Tittonell et al, 2020).

VII. RESULTS: NEW PROGRAMME

7.1. Local supply chain

By looking at the production flows of the *Onderste Hof* in the context of the stated problem of mass production, then the production of the potatoes and processing into French fries and their distribution is a well-functioning local system, a local production chain (Appendix figure 4.1). Which for example allows A. to choose his own local variety of potato. The other crops on the other hand are part of the regular production chains and are mainly used for secondary purposes. Therefore, some propositions

were made to localize the production flows of all the crops, so it can benefit local production chains and the chance to be detached from the regular market which demands for scaling-up.

7.2. Concepts of ecological awareness

This raises the question of how to select a sufficient production chain that will benefit both humans and non-humans and with a functioning business model. Food production, when combined with a social component, can potentially lead to greater awareness of where food comes from. However, this in combination with a more ecological way of farming requires a lot of labor from the farmer; more 'farmers' would have to be hired. Growing building materials is also an option. The demand for the sustainable building materials is increasing. The growth of building materials combined with a short chain, requires new (local) knowledge from different fields. If knowledge and labor are included, attracting new knowledge would lead to more diversity and a more varied palette of possibilities for a new farm concept that can contribute to more employment and material-awareness for the region. People working together can innovate 'the farm'. By combining more knowledge and different fields of expertise, an environment is created where real thought can be given to the future of the countryside.

Both food and materials could work, but creating awareness is an important part of building understanding of the value of ecology, the countryside and the primary producer: the farmer (Bignal, McCracken, 1996). Local harvesting and production connect the producer, by a material, with the maker and subsequently, by the product, with humans in general; a literal connection of people to the countryside. In doing so, making processes and agriculture transparent can also contribute; think of footpaths through the fields, showcases of natural materials or open workshops and ateliers. The farmer in addition can build up his own business over time where people start to appreciate the product and demand starts to rise.

7.3. Proposition: yields from cultivating raw materials

Current crops provide little residual product or already have a purpose (cattle feed). Maize for cattle feed could be replaced with maize for consumption where stem and leaf can be used to make materials such as press plates. The same goes for wheat and straw. The proportion of land used for secondary crops on the *Onderste Hof* is 38.5 ha. This could be used for the production of fibers, such as hemp and flax, and wood. Per crop, for example, 38.5/3=12.8 ha of land would then be available with a yield of 80.8 tons of flax and 100 tons of hemp. A 12.8 ha forest can produce 84.3 tons of wood per year, this wood is not qualitatively outstanding (Centraal Bureau voor de Statistiek, 2021). Hemp and flax are crops with great potential and increasing demand. It can be applied for the production of insulation, building components (pressboards or blocks of lime and fiber), composites and linen. Several machines can be purchased on a small scale to manufacture these products. Flax farmers use scutching and heckling machines to separate fibers for high-quality, natural linen. In this process, residual streams can be used for a variety of purposes like natural insulation (Engelen, L., 2015). A similar process can be applied to hemp. In both crops, the whole plant is used (Appendix figure 5.1).

Another argument for growing building materials, especially when considering wood, perennial flax or fast growing crops like hemp, is the sequestration of CO2. For this, models are being developed that seek to compensate farmers for capturing CO2 in crops. For the same crops, it is true that it contributes to biodiversity; forests and woodlots as discussed in section 3 and flax which is known for its resistance to pests and weeds and attracts insects. However, more common crops, such as sugar beet, a known for their ability to capture large amounts of CO2 (De Graaf, P., 2021).

7.4. Conclusion on a farm's programme

Growing raw materials could diversify a farm's programme. It can vary from studios, farm stores, workshops, and on-site processing of materials. The combination of knowledge can counteract ecological monoculture in the countryside and in the agricultural sector; the farmer is included in society.

VIII. CONCLUSIONS

How does analysis and optimization of material flows increase the potential of a new way to deal with our land and create new programme for farmhouses in Parkstad,Limburg?

Through the analysis of material flows, it becomes clear that there is a lot of potential for further utilization of residual streams. It also becomes clear that the residual streams of the current company are only a small part. In order to get local processing of residual flows off the ground, farms in the region could be linked together. A new programme could be a bioreactor or biorefinery for the region. Secondary products used as livestock feed can be replaced by a primary product and to use the land more efficiently in the context of food scarcity issues.

A new regional revenue model should emerge so that the farmer can make ends meet without having to scale up or change function. For A. the production of French fries is an important income, but not every farmer is capable of doing an investment like A. By combining knowledge of farmers, craftsmen and entrepreneurs and new functions it is possible to counteract ecological monoculture in the countryside and in the agricultural sector. When produced and processed locally, the farmer excludes transportation, which contributes to a better environment. When production processes become more visible, they can teach something about the identity of the region. A combination of production and ecological measures can balance the scale towards a more viable countryside.

Because low-intensity farming businesses are not yet economically viable, cooperation is essential and support from society must be enhanced. In the future, this may change: the province of Limburg wants to invest in preserving agriculture and is investing 20 million euros in the agricultural sector. No longer is the reduction of the price of the product the main focus, but the transition to more sustainable and circular production (Provincie Limburg, n.d.).

IX. REFERENCES

1. Agricola, H.J., Hoefs R.M.A., Doorn, van A.M., Smidt R.A., Os, van J. (2010). Landschappelijke effecten van ontwikkelingen in de landbouw. Retrieved October 26 from https://edepot.wur.nl/165289#:~:text=We%20onderscheidden%20de%20
2. Agrifirm. (2021, August 6). *Graanoogst 2021 tussen de buien door*. Retrieved December 7 from https://www.agrifirm.nl/nieuws/graanoogst-2021-tussen-de-buien-door/
3. Allesch, A., Brunner, H. (2015). *Material Flow Analysis as a Decision Support Tool for Waste Management*: A Literature Review. Retrieved October 25 from DOI: 10.1111/jiec.12354s
4. Ashour, T., Wu, W. (2011). *Using barley straw as building material. Barley: Production, Cultivation and Uses.* Retrieved December 13 from https://www.researchgate.net/publication/287478964_Using_barley_straw_as_building_material#fullTextFileContent
5. Bignal, E. M., McCracken, D. I. (1996). Low- Intensity Farming Systems in the Conservation of the Countryside. Journal of Applied Ecology , Jun., 1996, Vol. 33, No. 3 (Jun., 1996), pp. 413-424. https://www.jstor.org/stable/2404973
6. Brenner, N. & Katsikis, N. (2020). *Operational Landscapes. Special Issue:The Landscapists: Redefining Landscape Relations, 90(1), 22-31*. https://doi.org/10.1002/ad.2521
7. Bruins, M.E., Togtema, K.A., Meesters, K.P.H. (2014) *Succesfactoren kleinschalige bioraffinage*. Retrieved December 18 https://edepot.wur.nl/335754
8. CBS, PBL, RIVM, WUR (2021). *Bedrijfsgrootte en economische omvang landbouwbedrijven, 2000-2020* (indicator 2122, versie 10 , 8 juli 2021). Retrieved October 21 from https://www.clo.nl/indicatoren/nl2122- bedrijfsgrootte-en-economische-omvang-landbouwbedrijven-
9. Centraal Bureau voor de Statistiek. (2021, October 28). *Bruto opbrengst zaaiuien met bijna 20 procent toegenomen*. Retrieved December 2 from https://www.cbs.nl/nl-nl/nieuws/2021/43/bruto-opbrengst-zaaiuien-met-bijna-20-procent-toegenome
10. Centraal Bureau voor de Statistiek. (2021, October 29). *Akkerbouwgewassen; productie naar regio*. Retrieved December 2 from https://www.cbs.nl/nl-nl/cijfers/detail/7100oogs
11. Centraal Bureau voor de Statistiek. (2021, April 22). Landbouw; vanaf 1851 [Dataset]. Retrieved October 19, 2021, from https://opendata.cbs.nl/#/CBS/nl/dataset/71904ned/line?ts=1634570129090
12. Dawson, A., Norén, I., S. (2019). Inspiratie voor een biodiverse akker. Retrieved January 12 from https://edepot.wur.nl/504070
13. De Graaf, P. (2021). Keukenfabriek vindt koolstofboer. Volkskrant. Retrieved January 4 from https://www.volkskrant.nl/nieuws-achtergrond/keukenfabriek-compenseert-haar-co2-uitstoot-bij-de-lokale-boer-die-niet-meer-ploegt~bca21a49/
14. Deltaplan Biodiversiteitsherstel. (2021, February). Aanvalsplan versterking landschappelijke identiteit via landschapselementen. Retrieved on December 17, 2021, from https://www.samenvoorbiodiversiteit.nl/updates/2021/03-maart/raamwerk-aanvalsplan-landschapselementen-deltaplan-biodiversiteitsherstel.pdf
15. De Visser, C., Van Ree, R. (2016). *Small-scale Biorefining*. Retrieved December 18 from https://www.acrres.nl/wp-content/uploads/2018/03/Small-scale-Biorefining.pdf
16. Engelen, L. (2015). *De Kracht van Vlas.* Retrieved December 15 from http://www.dekrachtvanvlas.nl/sites/default/files/brochure_krachtvanvlas.pdf
17. Havermans, O. (2021, 16 September). In dit tempo is Nederland binnenkort wereldkampioen soortenverlies. Trouw. Retrieved October 6 from https://www.trouw.nl/duurzaamheid-natuur/in-dit-tempo-is-nederland-binnenkortwereldkampioen-soortenverlies~b6eaf940/
18. Janssens S.R.M, Smit A.B. (2016, January). *Reststromen consumptieaardappelen*. Retrieved December 7 from https://edepot.wur.nl/368097

19. Kennisakker. (2020). *Wat is de waarde van stro?.* Retrieved December 10 from https://kennisakker.nl/archief-publicaties/wat-is-de-waarde-van-stro3910

20. Locker, C.K. (2021, April 4). *Residual biomass utilisation in the potato and sugar beet processing industry: evaluation from a circular perspective*. [Master Thesis, WUR]. BSc, MSc and Internship library, WUR. Retrieved December 8 from https://bscmsc.pps.wur.nl/system/files/MSc%20Thesis%20Final%20Report%20CAKL%20PDF.pdf

21. Mangnus, E. (2012, July 2). *Meerjarige gewassen komen nauwelijks van de grond. VORK, 2019(2).* Retrieved December 10 from https://www.vork.org/nieuws/meerjarige-gewassen-komen-nauwelijks-van-de-grond/

22. Modelska, M.m Berlowska, J., Kregiel, D., Cieciura, W., Antolak, H., Tomaszewska, J., Binczarski, M., Szubiakiewicz, E., Witonska, I.A. (2017). Concept for Recycling Waste Biomass from the Sugar Industry for Chemical and Biotechnological Purposes. Molecules 2017, 22, 1544. https://doi.org/10.3390/molecules22091544

23. Mollison, B. (1997). Permaculture: A Designers' Manual. Ten Speed Pr.

24. Morandin, L., Long, R., Kremen, C. (2016). Pest Control and Pollination Cost–Benefit Analysis of Hedgerow Restoration in a Simplified Agricultural Landscape. Journal of Economic Entomology. 109. tow086. 10.1093/jee/tow086.

25. Mt.Pleasant, J. (2016). *Food Yields and Nutrient Analyses of the Three Sisters: A Haudenosaunee Cropping System.* Ethnobiology Letters , vol. 7(1), 87-97. https://doi.org/10.14237/ebl.7.1.2016.721

26. Provincie Limburg. (2017). Natuurvisie Limburg 2016. Retrieved October 26 from https://www.limburg.nl/publish/pages/203/natuurvisie_limburg_2016.pdf

27. Provincie Limburg. (n.d.). Beleidskader Limburgse landbouw- en agrifoodsector 2020-2023: Koers naar de toekomst. Retrieved October 20 from https://www.limburg.nl/onderwerpen/land-en-tuinbouw/limburgse-landbouw/

28. Runhaar, H. (2017). Governing the transformation towards 'nature-inclusive' agriculture: insights from the Netherlands. Revtrieved October 21 from https://doi.org/10.1080/14735903.2017.1312096

29. Sultana, J., Siddique, M.N.A. (2014). *Organic Potato Processing Problems and Potentials in Netherlands: A Review. Journal of Science, Technology & Environment Informatics, 1(1), 36-44.* DOI: 10.18801/jstei.010114.04

30. 'T Hoog, A. (2020). *From worthless leaves to valuable powder. Wageningenworld, 2020(1)*, 19-21. Retrieved December 8 from https://edepot.wur.nl/517352#:~:text=Each%20hectare%20of%20sugar%20beet,one%20to%20two%20per%20cent

31. Tittonell P., Piñeiro G., Garibaldi L.A., Dogliotti S., Olff H., Jobbagy E.G. (2020). Agroecology in Large Scale Farming—A Research Agenda. Frontiers in Sustainable Food Systems, Volume 4. https://doi.org/10.3389/fsufs.2020.584605

32. WUR. (n.d.). *Value from residual and side streams*. Retrieved December 7 from https://www.wur.nl/en/Research-Results/Research-Institutes/food-biobased-research/Solutions/Value-from-residual-and-side-streams.htm

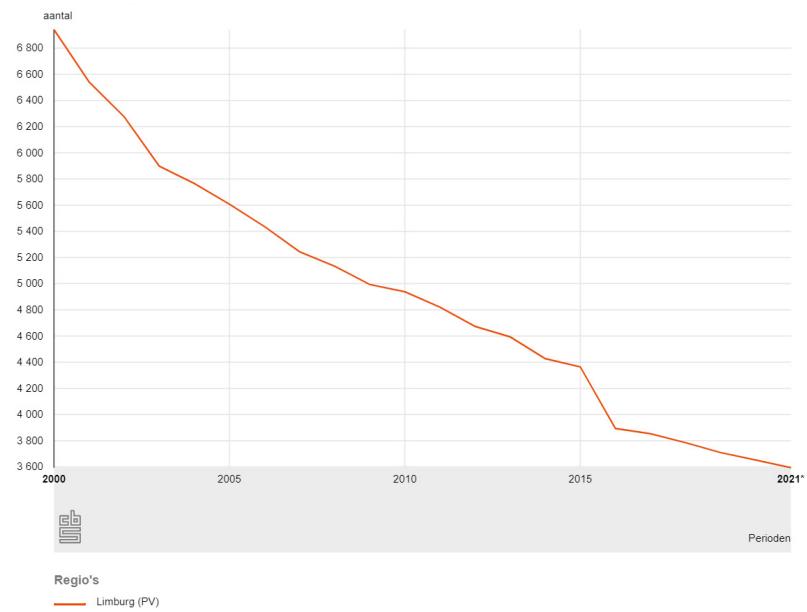
33. VPRO. [Video file]. (2019, September 15). Retrieved on December 14, 2021, from https://www.vpro.nl/programmas/tegenlicht/kijk/afleveringen/2019-2020/plattelandspioniers.html

34. VPRO. [Video file]. (2021, September 26). Retrieved on September 26, 2021, from https://www.vpro.nl/programmas/tegenlicht/kijk/afleveringen/2021-2022/boeren-burgers-en-beren.html

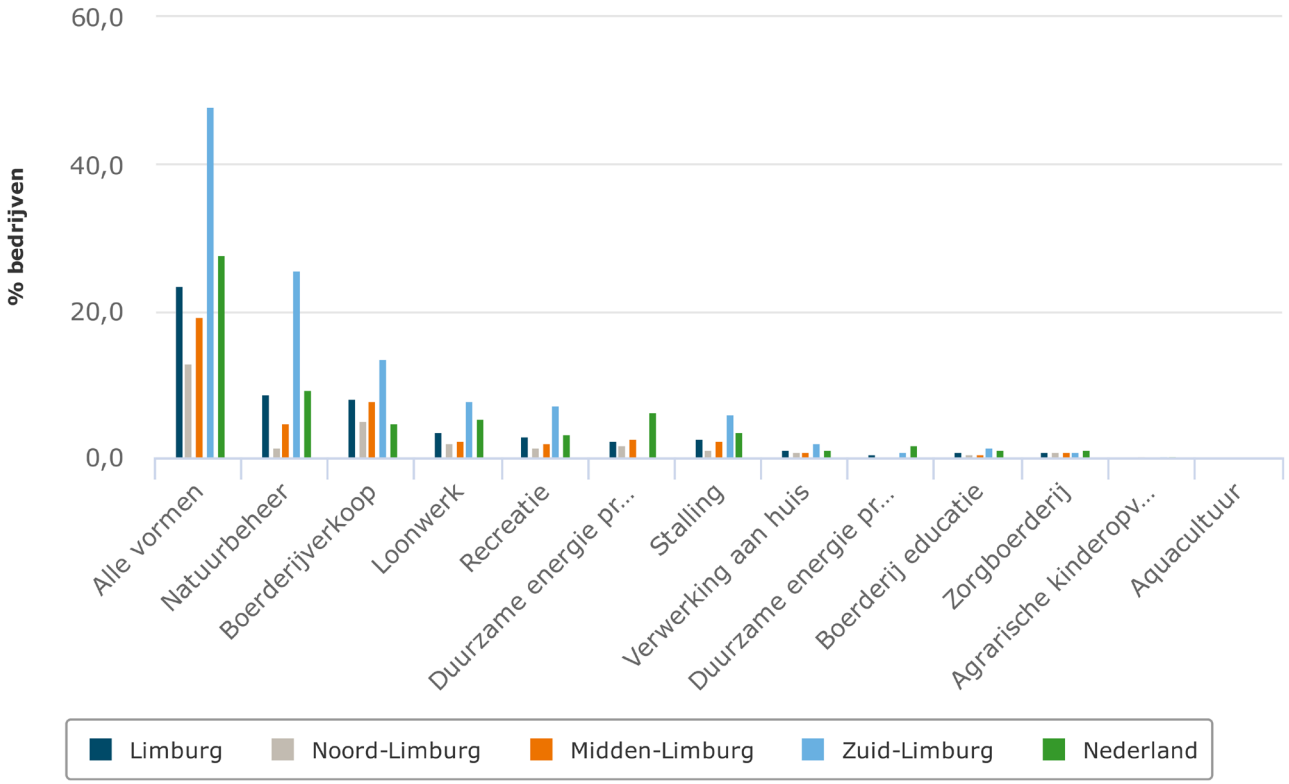
35. Zimmer, K. (2021, September 11). What the world can learn from Britain's humble hedge. Journal of Economic Entomology. Knowable magazine. 10.1146/knowable-110921-1

X. APPENDIX

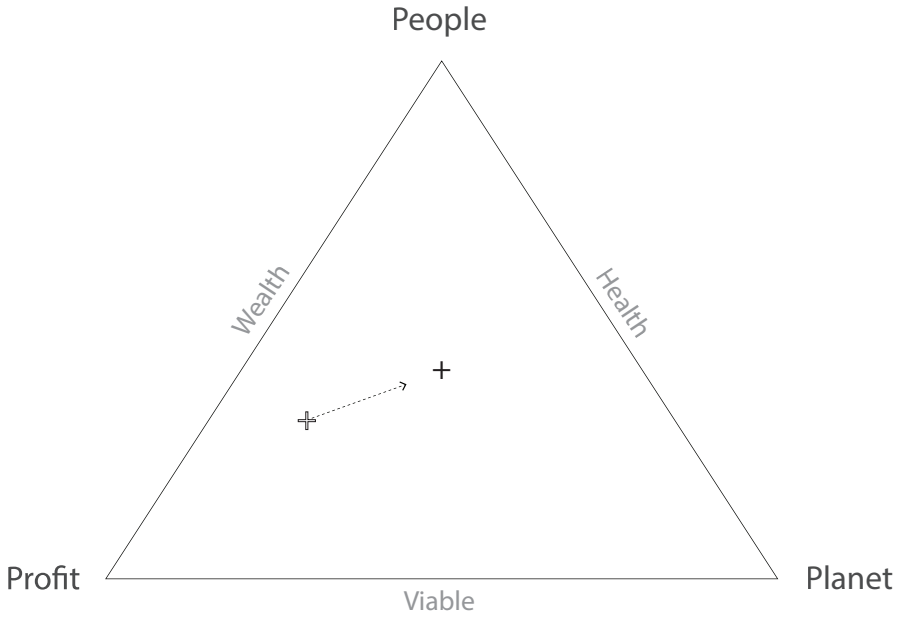
Figuur 1.1 Number of agricultural holdings in Limburg since 2000 (Centraal Bureau voor de Statistiek, 2021).



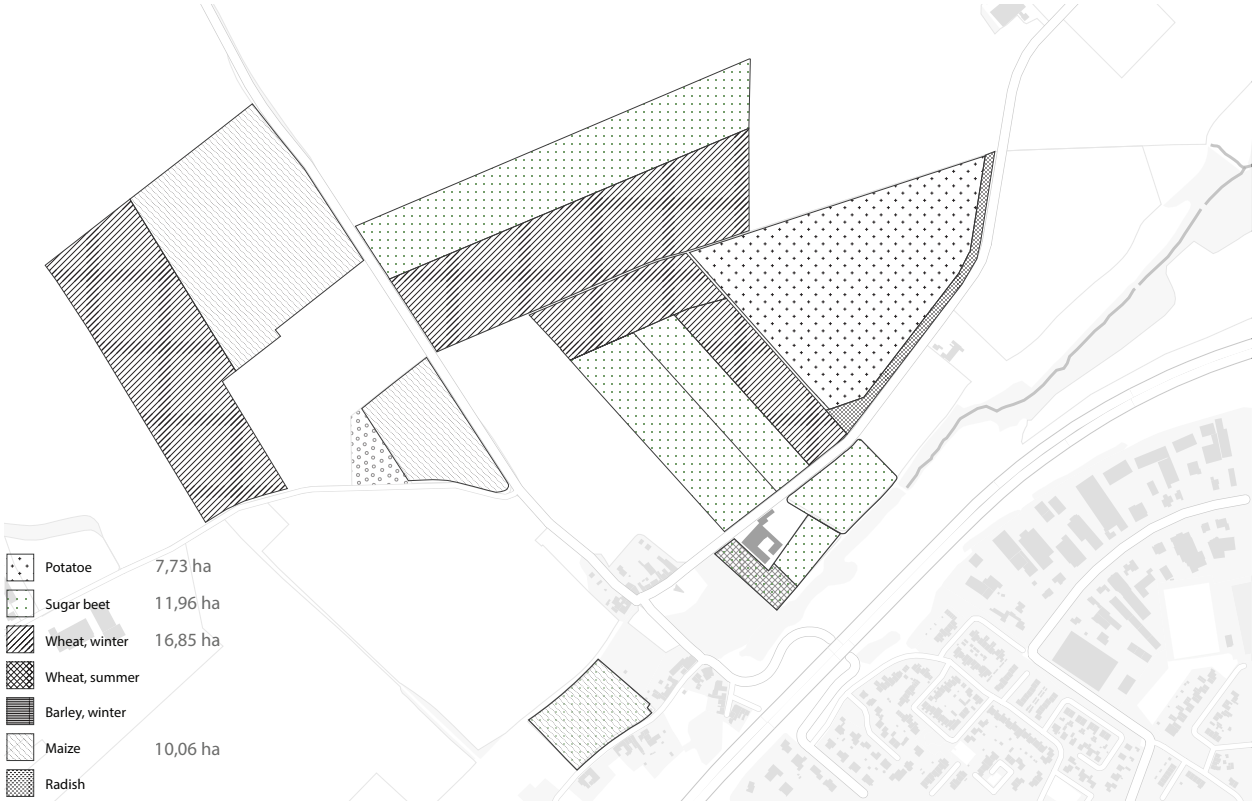
Figuur 1.2 Share of farms engaged in broadening (Agrimatie, 2018).



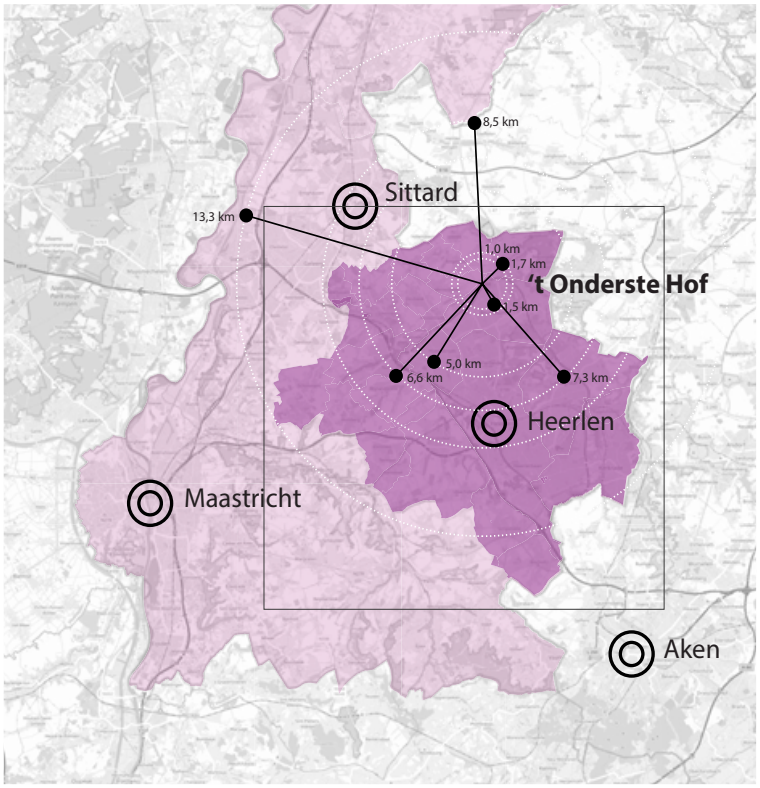
Figuur 2.1 Restoring the balance between human and non-human (image by author)



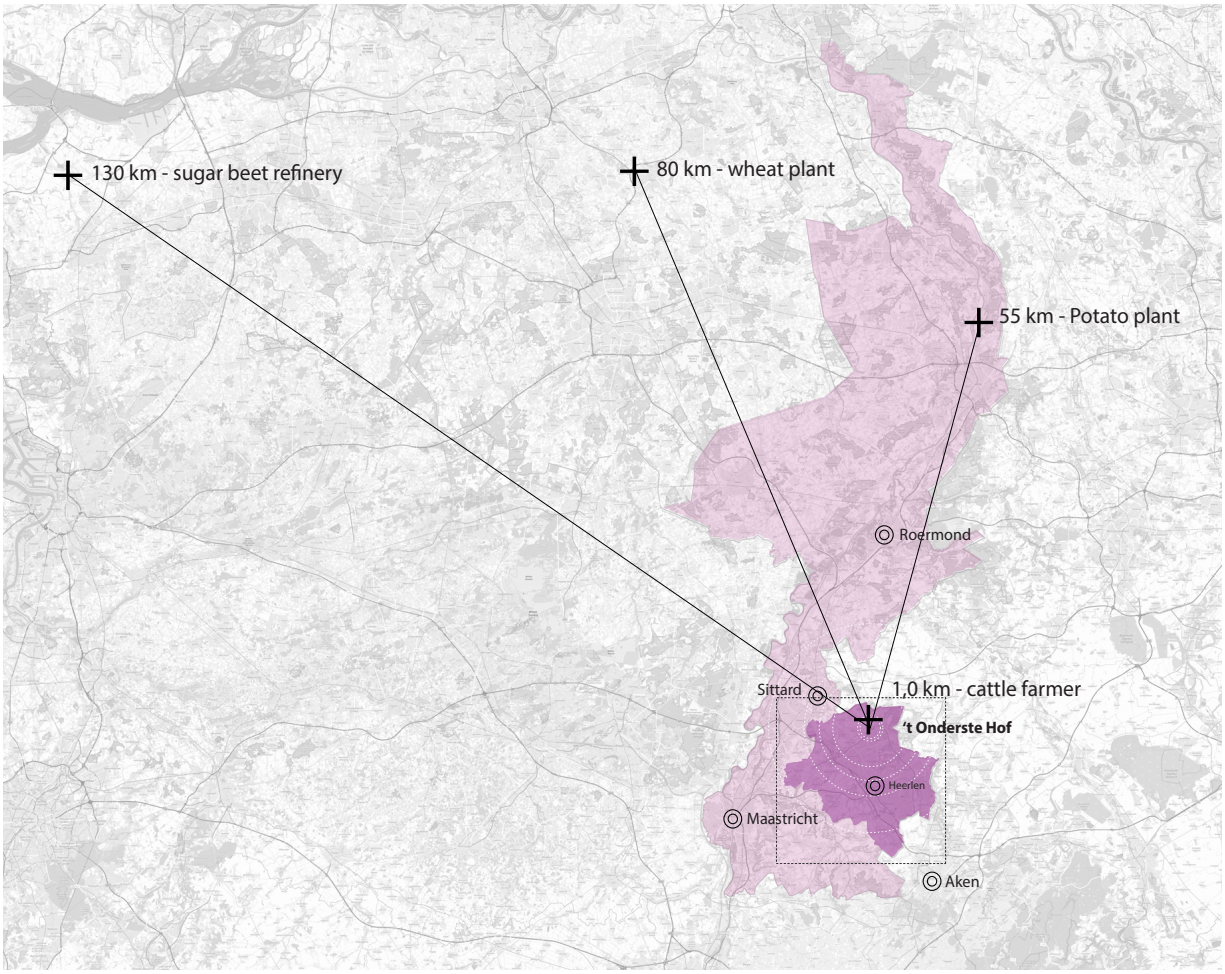
Figuur 3.1 Crops grown in 2021 on the Onderste Hof



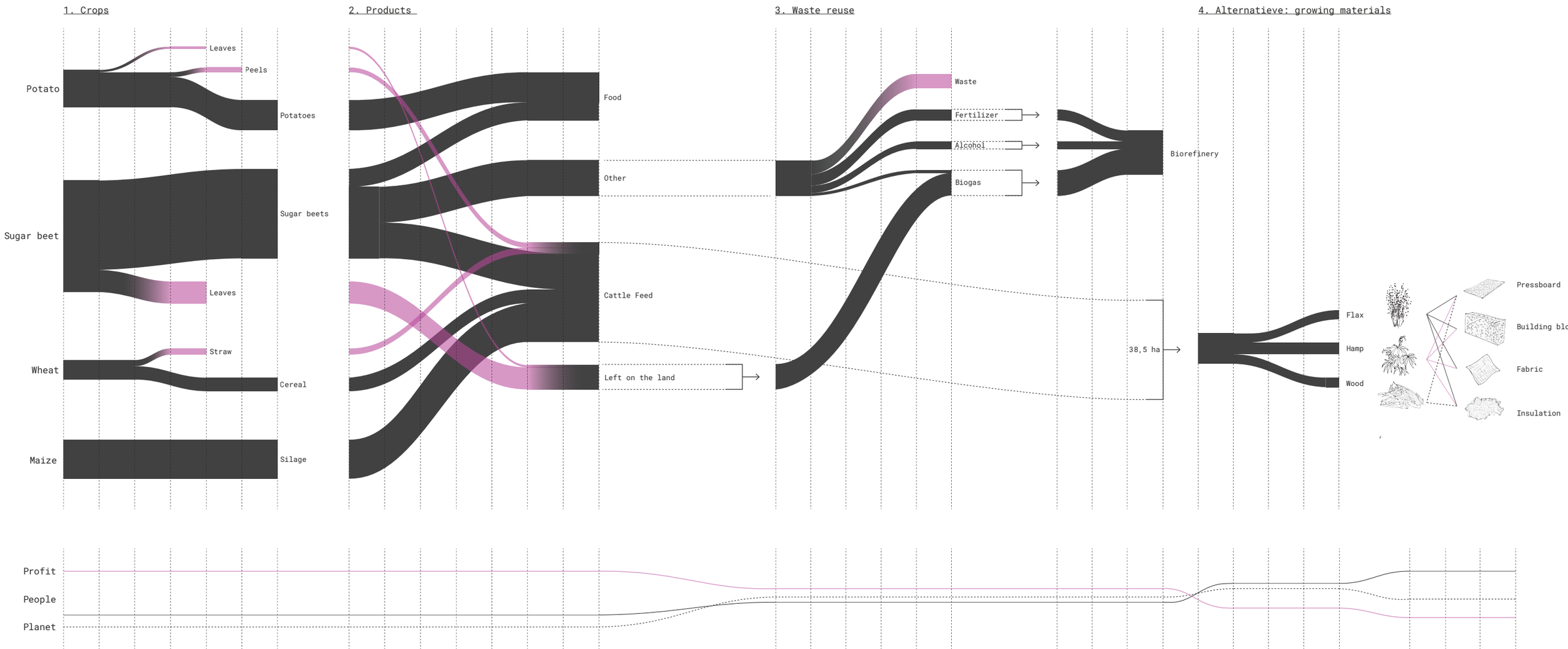
Figuur 4.1 Location of case study: Onderste Hof in the region of Parkstad, Limburg. A.'s customers of French fries are located within 13.3 km of each other.



Figuur 4.2 Disposal of agricultural products excluding French fries



Figuur 5.1 This (sankey) diagram provides insight into the inputs and outputs of the farm of A. as well as providing an alternative:growing materials. The quantities are expressed in biomass (tons). The entire diagram is checked with the people, planet, profit diagram at the bottom. The conclusion is a restored balance where 'planet' gets a larger share.



Figuur 6.1 Farming methods and landscaping elements plotted against their impact on people, planet and profit. With, in addition, other factors that may come into play in decision making

Figuur 6.2 diagram of possible interventions for circular agriculture (Dawson & Norén, 2019)