# Technology Innovations and Business Models for Valorisation of Industrial Waste Biomass in Sparsely Located Enterprises. Case: Industrial Symbiosis for Valorisation of Waste Biomass from Food and Beverage Industries (SYMBIOMA)

## *Sustainability in the potato-production*

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## EXECUTIVE SUMMARY

### Objectives

The focus in SYMBIOMA project is on improving waste utilization, and thus enhancing the overall sustainability in the agricultural sector. In this pilot report we examine how sustainability is perceived in the context of potato production in northern Norway, and we then utilize this knowledge to describe how the SYMBIOMA project might influence the sustainability in the potato production in the northern periphery region.

### Description of the work

The report relies on six sustainability assessments that were performed on potato farms in northern Norway and discusses its results to contextualize sustainability in potato production. The discussion further expands to include insights for the project's objectives and outputs.

### Results and conclusions

The results utilize the Sustainability Monitoring and Assessment Routine (SMART) farm tool to assess the combined farms' goal achievements on sustainability. These results come from both positive and negative statements that were generated by the SMART farm tool and support their underlying reasoning. The results are discussed against relevant contextual information and theoretical knowledge to describe sustainability at these farms and the potential for improvements. A key conclusion is that sustainability must be considered holistically – i.e., taking into account all the different effects on the environmental, economic, and social dimensions. In terms of the SYMBIOMA project, improved waste utilization should be viewed in its combined positive and negative consequences for all three dimensions.

## Contents

# 1. What is sustainability – a case study in the potato production in northern Norway

The concept of sustainable development was defined by the Brundtland Commission in 1987 and further developed through the UN's 17 sustainability goals (WCED, 1987; UN 2015). The purpose is to lead the development of humanity on earth in a better direction. A development that leads away from problems such as climate change, loss of biological diversity, hunger, illiteracy, and war. The concept is complex and concerns a development that ensures a robust economy and social welfare, in addition to being good for the environment, both for us who live today and for future generations. Even though emphasis is placed on sustainability in political documents at all levels as well as in research worldwide, we still have a long way to go before we can say that the world is developing sustainably (UN, 2019).

Sustainability is also high on the agenda in the agricultural sector, due to the fact that modern agriculture has led to several severe unintended impacts towards, for instance, climate gas emissions and loss of biodiversity (FAO, 2019; IPBES, 2019). 27 % of the global population support their livelihood through agriculture and therefore agricultural production has huge effects both socially and economically (FAO, 2021). Worldwide the agricultural produce is produced on a farm, and typically this is a family-run farm[1]. This is also the case in the Northern periphery areas of Europe (Natcher et al., 2021).

In the SYMBIOMA project the focus is on waste utilization, and a reason for this focus is that improved utilization of waste is also an important factor in enhancing sustainability in the agricultural sector. However, sustainability is a much wider and complex concept where trade-offs, synergies, as well as uncertainties of long-term effects, are a norm (Miller, 2014). To improve sustainability in the agricultural sector there is a need to thoroughly understand and appreciate what sustainability means. As the farm is the primary production unit, sustainability in this sector largely depends on how sustainable farms are.

In this pilot study we look specifically at sustainability connected to potato producing farms in the northern part of Norway. However, as similar natural conditions are found in the whole Northern Periphery area in Europe, the results are also interesting for the whole northern European region. The aim of this pilot study is to contextualize sustainability on farms in northern Norway and generate results that can be utilized in further processes to enhance sustainability in this region (Halland et al., 2021b).

[1] https://www.fao.org/family-farming/background/en/

## 2. Sustainability assessments through the SMART farm tool

In this pilot study we utilize the Sustainability Monitoring and Assessment Routine (SMART) farm tool to assess sustainability at farms in northern Norway. SMART farm is a tool developed by The Research Institute of Organic Agriculture (FiBL). SMART farm is based on the framework developed by The Food and Agricultural Organization of the United Nations (FAO), called Sustainability Assessment of Food and Agriculture systems (SAFA), (FAO, 2014). The SAFA framework has been developed to assess companies in the agricultural sector globally. It is an indicator-based assessment where sustainability is assessed in four dimensions: governance, environment, social, and economic, as well as in 21 themes and 58 sub-themes. SMART farm is therefore an operational farm assessment tool based on all the dimensions, themes, and sub-themes from SAFA.

In this pilot study we utilized SMART farm on six farms with potato production in northern Norway. All the farms have comparably large production areas of potato for this region, ranging from 5 to 40 hectares, and potato production amounts to a substantial part of the farms' income. SMART farm assesses the whole farm, and since the farms in northern Norway are multi-functional, most of the farms also have other income sources and production lines beside potato farming (Halland et al., 2021a). The assessments in this pilot study are performed during the 2020 – 2022 period.

The SMART farm assessments take about three hours to perform and involves inputs that the typical farmer readily know or that can easily be found by the farmers. After the assessment phase a report is generated containing the assessment results and including statements that are auto generated, explaining the positive and negative factors leading to the assessment results. The report is then reviewed together with the farmer.

## 3. Results of the SMART farm analysis

The results of the SMART farm assessments are shown as a percentage telling how well the farm fulfils the goal that is set in the specific theme or sub-theme. Figure 1 shows the combined results of the six farms over the four dimensions: Good Governance, Environmental Integrity, Economic Resilience, and Social Well-Being, and their scoring on the respective themes and sub-themes (black dots).

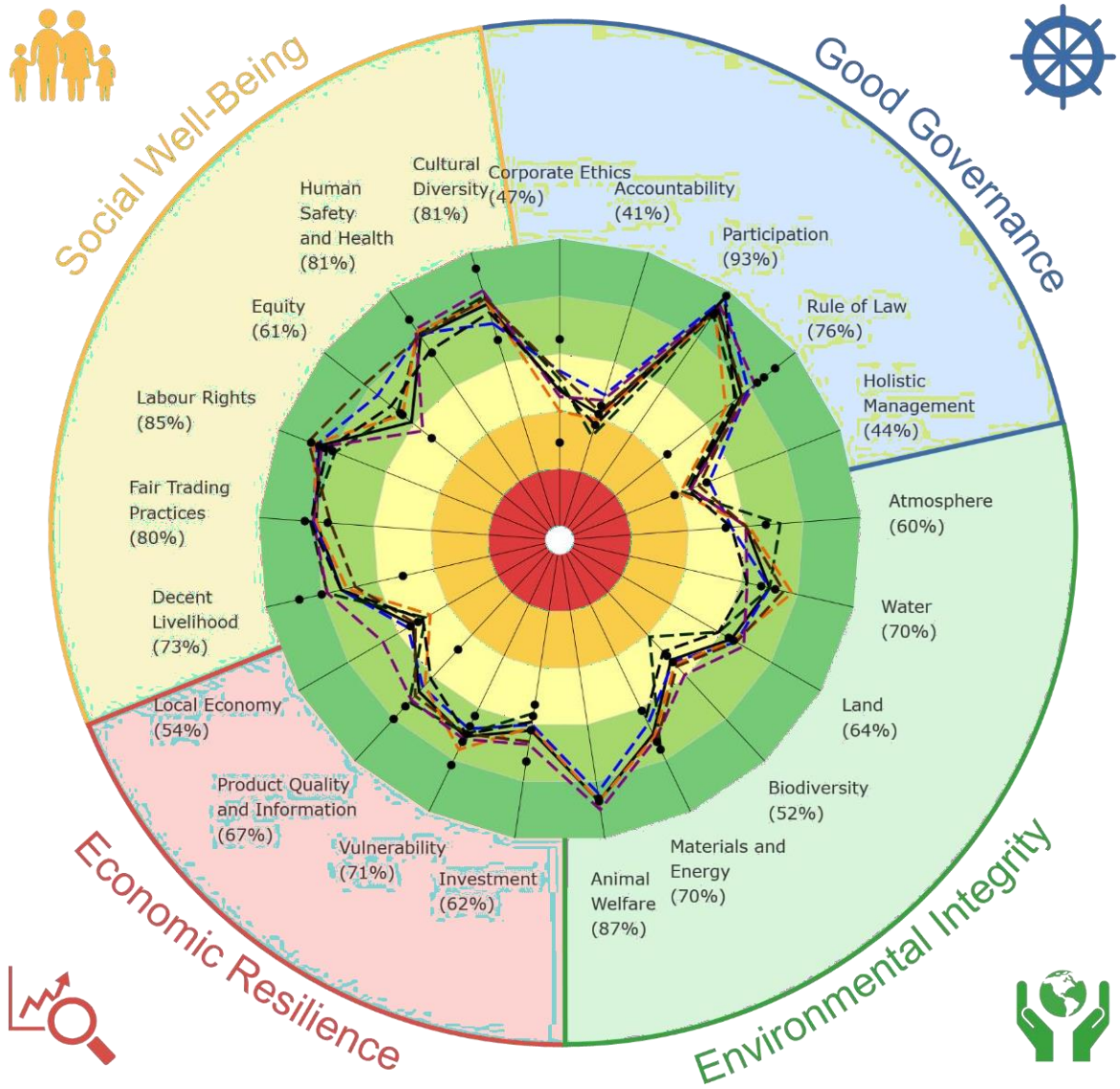


Figure 1. Results of the SMART farm sustainability assessments on six farms with potato production in northern Norway.

As a rule of thumb, percentages above 60 % can be considered a good score and appear in the light and dark green sectors in the diagram. To enhance sustainability at a farm it can be wise to start examining themes where scores are below 60 %, appearing in the yellow, orange, or red sectors of the diagram. As the assessment can be less context-specific (since it is developed to be used globally), the first question to ask is if the sub-themes are relevant or assessed correctly in the context of potato production in northern Norway.

Although there are differences between the farms, the results in Figure 1 also reveal that the six farms are quite consistent in terms of percent goal-achievement in the various themes. Prior research has shown that this might be due to contextual specifics, especially considering those regarding the national regulations and documentation requirements (Halland et al., 2021). The variations among the farms are often due to differences in the production system, differences in market options, and differences in transparency and degree of written plans and reports. In the discussion section the results will be discussed more in depth per sustainability dimension.

In addition, SMART farm results also show trade-off effects of the various production and business-related practices on the farm (Schader et al., 2016). For example, in this case study all the farms are conventional farms using pesticides to combat weed problems. This practice might negatively reflect on several themes in the environmental dimension such as biodiversity, land, and water; however, it might also reflect positively in the theme vulnerability in the economic dimension.

The SMART farm tool generates reports from each assessment as well as combined reports for several assessments in a project. These reports include statements indicating positive or negative score effects on the subthemes. Tables 1-4 show the statements with largest impact on the scores for the farms combined in the four dimensions.

Table 8. Positive and negative statements impacting the combined results from the farms in the Good Governance dimension.

| **Good Governance** | |
|---|---|
| **Positive** | **Negative** |
| The farm manager can provide detailed information on sustainability improvement measures.<br><br>The farm successfully and in the long term cooperates with other farms.<br><br>The farm has a close cooperation with customers/buyers.<br><br>The farm engages in social matters in the community.<br><br>The farm supports or takes part in political or social activities for improving regulations (laws) in the social and/or environmental spheres.<br><br>There were no incidents in the last five years in which the farm has been blamed for negative impacts on humans or the environment.<br><br>There have been no environmental and/or social conflicts in the past 5 years with stakeholders or respect, mutual understanding and fairness have been considered when resolving such conflicts.<br><br>There have been no cases in which the farm has violated the law within the past five years.<br><br>There are or were no conflicts with other water users in the farm's vicinity over access to water, water quality or he volume of water used.<br><br>The person in charge is certified to use plant protection and/or veterinary drugs.<br><br>The employees are completely free to assemble or engage in bargaining. | The farm has committed itself in writing to the principles of sustainable development, but this is not available to the public.<br><br>The farm does not have a written, publicly available plan for future improvements in its sustainability.<br><br>The farm has not carried out a sustainability report covering all (covering all sustainability dimensions) within the past five years.<br><br>The farm has not published a sustainability report within the past five years.<br><br>The farm does not consider the external environmental and social costs and benefits in its accounting.<br><br>The farm is not/is only slightly committed to environmental protection outside of the farm's land.<br><br>When purchasing farm inputs, the farm does not consider or rarely considers social or environmental criteria or certifications for the five most important farm inputs.<br><br>Only a few or no sales products are certified by a third-party certifier to carry a social- or eco-label. |

Table 9. Positive and negative statements impacting the combined results from the farms in the Environmental Integrity dimension.

| **Environmental Integrity** | |
|---|---|
| **Positive** | **Negative** |
| None or only a small part of the utilized agricultural area has become degraded over the past 20 years and/or can no longer be used for farming.<br><br>None of the arable land was formerly peatland.<br><br>Mineral potassium fertilizer is used in a needs-oriented way.<br><br>It can be ruled out that manure from livestock treated with antibiotics is applied.<br><br>Operational/commercial waste is disposed correctly.<br><br>There is no danger of direct point source emissions of nutrients and pollutants to the atmosphere and water bodies (incl. wells and drinking water sources) on the farm and its utilized areas.<br><br>The whole or a large part of the agricultural area does not receive synthetic chemical insecticide applications.<br><br>There are no riparian strips or these are extensively managed. This reduces the risk of adverse nutrient and pollutant discharges into surface waters.<br><br>A large part of the farm's area consists of areas to promote biodiversity.<br><br>No pesticides are used or the pesticides used are not considered to be very persistent in soil.<br><br>Heated farm buildings are sufficiently insulated.<br><br>A large portion of the electricity consumed derives from renewable resources. | A large part of the agricultural area receives synthetic chemical herbicide applications.<br><br>The pesticides used are toxic to aquatic organisms. Some of the pesticides used are very persistent in water. Comparatively many different pesticides (active ingredients) are used.<br><br>A significant portion of the farm's current agricultural area was deforested over the past 20 years.<br><br>The crop rotation only consists of very few elements. No or only a small part of the land under crop rotation has cover crops undersown. No or only a small part of the agricultural area is mulched.<br><br>No or only an immaterial part of the land under crop rotation is maintained with a green cover during autumn and winter.<br><br>Zero / no-tillage is not applied or only applied to a small portion of the agricultural area.<br><br>No or only a very small portion of the fuel consumed is provided by renewable resources. The fuels used for farm vehicles and machinery are not produced on-farm.<br><br>The farm doesn´t use reusable and multiple-use packaging. |

Table 10. Positive and negative statements impacting the combined results from the farms the Economic Resilience dimension.

| **Economic Resilience** | |
|---|---|
| **Positive** | **Negative** |
| A professional agricultural bookkeeping is used.<br>In the last five years, the yields have been stable or improving. In the last five years no lower yields resulted from water shortages.<br>The farm's profit has been rising or stable in the last five years.<br>The farms liquidity is ensured.<br>The farm invested in long-term improvements of the infrastructure (buildings, machines, roads) and/or purchase of further production land in the last ten years. The general condition of the farm infrastructure is good or very good.<br>The farm has access to formal or informal financial sources in times of need.<br>A large portion of farm inputs comes from contracted suppliers or stable long-term suppliers. There have been no occasions in the last five years where farm inputs were not available.<br>The farm invests in further training of the farm manager or employees.<br>The farm is aware and informed about future political, market and climate change challenges.<br>Farm succession is secured.<br>The farm has a close cooperation with customers/buyers.<br>Transparent details of the production methods used on the farm are available to buyers.<br>No products have been returned by buyers in the last five years.<br>The farm is insured against damage from fire and natural disasters relevant to the region (flooding, landslips, etc.).<br>The farm has additional sources of income besides farming (on and off the farm).<br>The fluctuation of permanent personnel was very low or there was neither permanent nor temporary personnel in the last five years.<br>All or a large proportion of the workers have social protection.<br>The farmer has absolute legal rights of at least 10 years over the land. | Alternative markets do not exist for all products if buyers drop out.<br>The farm does not sell its products via direct sales channels or generates a substantial portion of its income from it.<br>On average some portion of food produced for human consumption had to be disposed of over the past five years to sewer, landfill, incineration without energy recovery or spread on field.<br>Apprenticeship and/or traineeship places are either offered only on rare occasions or their excessive number threatens the quality of the training.<br>When purchasing farm inputs, the farm does not consider or rarely considers environmental criteria or certifications for the five most important farm inputs.<br>Only a few or no sales products are certified by a third-party certifier to carry an eco-label or a social label.<br>Only a few employees had access to external training in the past five years.<br>Some of the pesticides used are very persistent in water (half-life > 60 days) according to the "PAN Pesticide Database". |

Table 4. Positive and negative statements impacting the combined results from the farms in the Social Well-Being dimension.

| **Social Well-Being** | |
|---|---|
| **Positive** | **Negative** |
| The farm engages in social matters in the community.<br><br>The physical workload by the harvesting technique is materially reduced due to the degree of mechanization on the farm.<br><br>A professional management system for workplace safety and health is in place.<br><br>There were no or only very few occupational injuries or work-related illnesses in the past 5 years.<br><br>It is ensured that workers are appropriately protected during the application of pesticides and other hazardous materials.<br><br>A large portion of farm inputs comes from contracted suppliers or stable long-term suppliers.<br><br>It can be ruled out that the farm's suppliers were involved in one or more incidences of child labour and forced labour in the past 10 years.<br><br>All employees have a signed written legally binding employment contract. All workers have a work permit and are registered with the authorities.<br><br>Employees can join unions without any problems. The employees are completely free to assemble or engage in bargaining.<br><br>When children below 16 help with the work, it can be ruled out that this work is hazardous to their health or development, nor is their school performance impaired by that work.<br><br>The fluctuation of permanent personnel was very low or there was neither permanent nor temporary personnel in the last five years.<br><br>Women, men, minorities, and vulnerable groups receive equal pay for equal work/output at the farm.<br><br>All or a large proportion of the workers have social protection.<br><br>There have been no incidences of workers being harassed or mobbed during the last five years.<br><br>The farm invests in further training of the farm manager or employees. The farm has adequate access to extension services and training. | When purchasing farm inputs, the farm does not consider or rarely considers social criteria or certifications for the five most important farm inputs.<br><br>Apprenticeship and/or traineeship places are either offered only on rare occasions.<br><br>When providing training, no competences/knowledge relating to environmental, social, and economic sustainability have been taught.<br><br>Only a few employees had access to external training in the past five years.<br><br>No disabled people work and/or live at the farm.<br><br>A large part of the agricultural area receives synthetic chemical herbicide applications. The pesticides used are toxic to aquatic organisms. |

# 4. Discussion

In general, the results of the assessments are good, since combined the farms score above 60 % in 15 of the 21 themes assessed. However, there will always be room for improvements, and since the context and the specific production on the individual farms differ, solutions must be found locally (Darnhofer et al., 2010). In addition, trade-offs between themes and dimensions must be considered, meaning that extra care must be taken when planning for changes in a theme to assure that they may not lead to negative consequences for other themes. Some known trade-offs appear, for instance in what is good for environmental sustainability and what is good for the economic sustainability (Schader et al., 2016). In the rest of this section, we discuss the results in each of the four dimensions: Good Governance (Section 4.1), Environmental Integrity (Section 4.2), Economic Resilience (Section 4.3), and Social Well-Being (Section 4.4). The last section (Section 4.5) discusses how the SYMBIOMA project can influence sustainability in the potato production.

## 4.1 The Good Governance dimension

In the Good Governance dimension, the reported scores show high variation between the different themes (from 41% to 93%). Lower scores are mainly due to that the farms do not have a comprehensive (preferably written) plan for sustainability, a plan that can be evaluated and changed accordingly throughout the season. In addition, farms do not produce sustainability reports. In Norway, there are to this day no systems or standardized protocols available for farmers who want to create such comprehensive sustainability plans and reports.

Nevertheless, the documentation requirements in agriculture in Norway remain very high, and through, among other things, KSL - Quality system in agriculture, much of the content in a sustainability plan and report is already present. The lower scores might therefore to some degree be due to the fact that the assessment tool is not context-specific enough to capture such-contextual specificities. Another indication to support this is that the Governance dimension has synergy effects on the other three dimensions (Environment, Economics and Social) (Schader et al., 2016) and therefore a lower score in the Governance dimension should be followed by lower scores in other dimension. Since this is not observed, it might suggest then that planning for sustainable production is to a large degree present also in the north Norwegian potato producers. In other studies, high documentation and regulation requirements is found to enhance farm sustainability (Kiełbasa, 2018).

The Governance dimension can be a good place to start working for an enhanced sustainability in the potato production, by more explicitly making plans and reports for the farms' sustainability. This might also spur the farmers' awareness of the concept contextualized to their specific farm (Halland et al., 2021b).

In this dimension, not only what happens on the farm is assessed, but the dimension also connects the farm to the impact its production has on a more global level. For instance, in the assessment the farmer is asked to consider where, and under what conditions, the inputs are produced. For the farmer however, there are often few alternatives to choose from, and the farmers, to a large degree, must rely on to the suppliers who are the ones taking this responsibility. Farmers report that they have high trust in the larger, often coop-owned, Norwegian wholesalers, although it is wise to maintain some healthy scepticism on this arrangement (Halland et al., 2021b).

Overall, much is positive in this dimension. There are no conflicts to be traced and the farmers have good contact with the local community and others who may be affected by the farm operation. The ability to cooperate as well as social learning are both highly connected to enhancing sustainability (Halland et al., 2021b). The farmers are also largely aware of developments and changes in the market, in the policy, and the forecasts for climate change for the area. Such awareness is found to spur resilience (Darnhofer, 2010).

## 4.2 The Environmental Integrity dimension

In the Environmental Integrity dimension, the goal achievement varies between 60% to 87%. The highest score is found in the animal welfare theme. Even though the focus is on farms with potato production, in northern Norway due to the short plant growing season and to a large degree, the absence of large-scale horticultural farmers, all farms also have other income sources besides potato production. Therefore 75 % of the horticultural producers also practice husbandry to various extents (Halland et al., 2020). In these six assessments three of the farms had animal production.

What counts negatively in the assessments is, for instance, the use of chemical pesticides. In Norway, certification is required for the purchase or use of pesticides. This means that farmers know the risk, use protective equipment, and all the farmers have spraying plans. In addition, strict regulations on pesticide approval apply. However, at present it is difficult to see how potatoes can be efficiently produced without chemical pesticides due to weed and disease challenges in potato production. Precision spraying and alternative methods (such as fibre-covers) is however a continuous focus.

Farmers regularly take soil samples and based on these results the fertilizing levels are determined. All farms have fertilizer plans, and this is also a topic of continuous improvement, for instance with precision fertilization. At the pilot study farms, soil degradation and compaction do not appear to be a problem, and all farms practice methods to avoid compaction, such as fixed driving paths and low-pressure tires.

All participating farms have access to enough water of good quality. Drought episodes are seldom in northern Norway, where on the contrary it can be too much precipitation in the harvesting season that may create challenges (Nøstvold et al., 2019).

The farmers practice crop rotation, but most often with a small selection of crops due to the limited land that is suitable for horticultural production, and the few possibilities besides perennial grasses. Moreover, the short growing season results in the soil not being covered with vegetation over the winter, and this leads to greenhouse gas emissions. This situation can be challenging to address due to the late harvest with few possibilities for attaining a cover crop. The potato fields are all annually ploughed before planting the seed potatoes.

The lowest score has been found in the theme of biodiversity, but since less than 1% of the area in the north is cultivated land, it is conceivable that agriculture has a less negative effect on biodiversity than in more intensive agricultural areas. The farms are also relatively large consisting of much natural vegetation, forest, mountains, and lakes, where the nature to a large degree is kept unaltered. When it comes to arable land, few measures specifically targeting for increasing biodiversity are implemented.

Although the water sufficiency in Norway provides big amounts of renewable energy from hydropower, diesel is still the fuel used for tractors and other machinery at all the farms. Presently, only one of the six farms produces part of their own energy. In the Norwegian agriculture in general, there is an increased interest in investing in renewable energy at the farms (LMD, 2022). For all the six farms, the agricultural waste is delivered to public waste companies, where it is handled according to national regulations. However, agricultural plastic waste is in other studies found to be a challenge (NIBIO, 2019). Renewable packaging material for the potatoes is not yet feasible due to the risk of spreading potentially dangerous potato diseases, such as potato cyst nematode.

## 4.3 The Economic Resilience dimension

In the Economic resilience dimension, the goal achievement varies between 54% to 71%. In the SMART farm assessment, influence on social or environmental factors are also considered economically. For instance, in the theme Investment also measures to avoid or restore damage to soil, water and atmosphere is considered as well as investments in

competence building or workers health and security. Also, in the theme Vulnerability, for instance the farmers awareness about future political, market and climate change challenges, is expected to ease the farms vulnerability to such changes. Due to this environmental or social factors to a large degree also influences the results in the economic dimension.

On these six farms, the income from potato production fluctuates from year to year. However, in the last five years, profits are stable or have increased, liquidity is good, and jobs have been created. The farms invest in infrastructure, and buildings and machinery are generally in good condition. However, we also see that for many, loans make up a high proportion of the farm's value. All these farms also have additional sources of income besides farming, and this reduces the economic vulnerability of potato production. It should be acknowledged that the assessment-years are 2019 and 2021. Higher prices on many of the inputs necessary for agricultural production is seen in 2022, and this might decrease profits (LMD, 2022). As the income from potato production to a large degree comes after the produce is sold, and the expenses largely accumulates during production, an increase in expenses is expected to decrease the farms liquidity.

In general, farms are much dependent on one farmer, and many are poorly secured if he or she becomes ill or has an accident. For some, it is also not clear who will take over the farm, which could make the future more uncertain (Halland et al., 2021a). However, on these six farms the farmer is either younger than 45 years or succession is clear.

The market situation varies from farm to farm. In general, direct sales gives a significantly higher price for the products, but this requires the farmer to take on the processing and sales work himself, which often limits the production volume. Five of the six farmers sell most of their yield to a wholesaler, and since there are few wholesalers left in northern Norway, alternative markets might not exist if the buyer should drop out, this might increase vulnerability. However, all farmers report that they have close cooperation with their customers/buyers. In addition, all farms report that they have stable long-term suppliers for the necessary input.

Local businesses contribute positively to the local economy. They pay taxes to the municipality and buy input and services locally. However, the largest purchases the farms have, such as fertilizer, pesticides, seeds, or packaging material, might not be possible to buy locally.

## 4.4 The Social Well-Being dimension

In the Social Well-Being dimension, goal achievement varies from 61% to 85% between the themes. In Norway, many topics within this dimension are regulated by law, such as employee rights, food safety and health and safety measures, and for themes related to such topics the producers score high in the assessment. Within such themes (Labour Rights or Human Safety and Health) in general, the differences between farms´ scores are small.

The farmers contribute positively to their local communities. They engage in social matters and buy much of their inputs and services from local businesses. The assessments in this dimension do not only reflect on what occurs on the specific farm, but also how the farms' practice and production influences workers or societies on a more global scale. Notably though, most of their largest inputs are not produced locally. SMART farm results are negatively affected by the fact that few of these inputs are chosen due to social certifications. In practice, the farms have few options to choose from. As they all buy their inputs from national (often farmer-owned) input providers which they trust, as far as they know, these inputs are produced by workers who have satisfactory social conditions. The farmers also buy inputs from stable long-term suppliers.

These six farms are all family-farms, and because of this fact as well as the fact that the plant growing period is relatively short in the northern regions, external employees are mainly seasonal and only necessary during harvest season. In addition, all farms have other income sources besides potato-production, and therefore half of the farms also have external full-time workers that are also working in other farm activities. The farms practice equal pay and anti-discrimination, but no one has written commitments against discrimination, and to a small extent facilitates work for people with different challenges. In general, the typical farmer has a high workload, and some have few days off during the year. Overtime for employees is only partly compensated for. The employees have working contracts and are free to join workers' unions. There is little focus on external training and skills development for external and part-time employees, but most farmers yearly spend a few days on competence building. In addition, all these farmers have good access to extension services.

All farmers are aware of safety hazards on their farm, they have plans for health and safety measures and utilize protective gear where necessary. Farmers are certified for the use of pesticides, and therefore they know hazards that may be related to such products. Traditionally horticultural production implied hard physical labour but the high degree of mechanization has significantly reduced this. The farms report none or only very few work-related injuries over the last five years.

## 4.5 The SYMBIOMA project's influence on the sustainability of the potato production

In the SYMBIOMA project the focus is on valorisation of the organic waste from the potato production. This waste is identified in the SYMBIOMA project coming from the production on the farm, as well as in the upstream value chain through storage and processing of the potatoes, and constitutes of out sorted potatoes, damaged or rotten potatoes, and potato peel (Reim et al., 2020). Today much of this waste has low or even negative value for the farmer or processor as much of it is dumped in landfills/compost or utilized as animal feed. Possibilities for higher value utilization have been identified, such as further processing to starch, ethanol, additives for foodstuff, etc. Improved utilization of the organic waste will influence all the dimensions of sustainability assessment described in SAFA and assessed in SMART farm.

In the Economic Resilience dimension, improved waste utilization influences the profitability of the production by gaining a higher value of the available yield. However, it might also lead to higher investment needs in infrastructure and investment in new knowledge and competence. This is identified as a bottleneck to valorise potato waste at farms or smaller processing plants, since the relatively low volume of organic waste, does not make it possible to support larger investments (Reim et al., 2020). The solution for smaller companies can therefore be to cooperate on waste valorisation to increase the waste volume considerable. For instance, in Norway this is successfully accomplished through the Hoff[2] cooperation where several hundred farmers and processing companies transport their organic waste to common processing plants for various potato derived products. However, this gives trade-offs to the environmental dimensions since it requires long transportation of the waste material. In addition, the profitability of this practice for the individual farm or processing plant is reportedly low. Enabling local processing of the potato waste, could increase the local economy through higher value creation as well as creating synergy effects on the social dimension, if it leads to more jobs that are created locally.

In the Environmental Integrity dimension improved waste utilization directly influences the waste reduction since this organic matter no longer will be classified as waste, but rather a raw material for further processing. Potato waste might also pose a risk of spreading diseases through the soil of unwashed potatoes. This particularly concerns the potential spread of the potato cyst nematodes (Reim et al., 2020). In addition, a higher utilization of the already produced potato yield for human consumption, reduces the carbon footprint per weight unit produced. However, by further processing this organic matter, more energy and various materials might negatively affect the overall sustainability score. As the waste

[2] https://www.hoff.no/199/baerekraft

currently is utilized both as compost or as animal feed, the current utilization might have positive effects on soil improvement or on local self-sufficiency of feed. This might also positively affect the local economy.

In the Social Well-Being dimension, the improved waste utilization might lead to the creation of more jobs locally. In the northern areas potato production is restricted to the short summer season and because of this most farms have additional livelihoods/productions on the farms in order to be able to sustain the farm income (Halland et al., 2021a). Improved valorisation of the waste might influence the possibility to attain a decent livelihood of a farm or a processing company and require improved capacity development of the workers.

In SAFA (and SMART) Good Governance is added as a fourth dimension (FAO, 2014). This dimension can give synergy effects on the three other dimensions Environment, Economy, and Social Well-Being (Schader et al., 2016). The SYMBIOMA project has to a great extent focused on this dimension. In this regard the project has developed a Technology Innovation Platform (TIP) that is digitally available for all interested parties (symbioma.eu). The focus on the TIP is to provide food industry with services connected to waste biomass valorisation in terms of both business development and technology development. TIP can be utilized to identify new products or intermediates from process waste or side streams, assist companies in adopting circular business models, and to form new resource-efficient value chains. Holistically planning for waste utilization is a prerequisite for attaining sustainable waste utilization and circular economy on the farms.

## 5. Conclusions

In this pilot report for the potato industry sector we discussed the results from six sustainability assessments on farms in northern Norway across relevant contextual information and theoretical knowledge. We discussed both positive and negative factors for sustainability in the potato production regarding the four sustainability dimensions used in the SAFA framework (FAO, 2014). In general, the farms score high on the assessments, although there are always possibilities for improvements. There are variations among the farms, but the trends to which themes the farms score higher or lower at are quite consistent between farms, and to a large degree reflects contextual conditions prevalent in the Norwegian agriculture (Halland et al., 2021b). In addition, we utilized this knowledge to describe how the SYMBIOMA project might influence the sustainability in the potato production in the northern periphery region.

The conclusion to this pilot study is that sustainability must be considered holistically, at the same time considering all effects on the environmental, economic, and social dimension. Following, for the SYMBIOMA project, improved waste utilization should be viewed according to its combined positive and negative consequences for all sustainability dimensions.

## 6. References

Darnhofer, I. (2010). Strategies of family farms to strengthen their resilience. Environmental Policy and Governance, 20(4), 212-222. https://doi.org/10.1002/eet.547

Darnhofer, I., Bellon, S., Dedieu, B., and Milestad, R. (2010). Adaptiveness to enhance the sustainability of farming systems. A review. Agronomy Sustain. Dev. 30, 545–555. doi: 10.1051/agro/2009053

FAO (Food and Agriculture Organization). (2014). SAFA Sustainability Assessment of Food and Agricultural Systems – Guidelines. Version 3.0. Rome. https://www.fao.org/3/i3957e/i3957e.pdf

FAO (Food and Agriculture Organization). (2019). FAO's work on climate change. United Nations Climate Change Conference 2019. https://www.fao.org/3/ca7126en/CA7126EN.pdf

FAO (Food and Agriculture Organization). (2021). World Food and Agriculture – Statistical Yearbook 2021. Rome. https://www.fao.org/3/cb4477en/cb4477en.pdf

Halland, H., Bertella G., and Kvalvik I. (2021a). Sustainable value: the perspective of horticultural producers in Arctic Norway. International Food and Agribusiness Management Review: 24 (1), 51–70.

Halland, H., Lamprinakis, L., Kvalvik, I., and Bertella, G. (2021b). Learning for sustainability in horticultural production in Arctic Norway. Frontiers in Sustainable Food Systems, 5(320). doi:10.3389/fsufs.2021.686104

IPBES, The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

Kiełbasa, B., Pietrzak, S., Ulén, B., Drangert, J.-O., and Tonderski, K. (2018). Sustainable agriculture: the study on farmers' perception and practices regarding nutrient management and limiting losses. Journal of Water and Land Development 36(1): 67-75. https://doi.org/10.2478/jwld-2018-0007

LMD (Landbruks og Matdepartementet). (2022). Statens tilbud, Jordbruksforhandlingene. https://www.regjeringen.no/contentassets/fecca3039e9245fb91710a79405444ad/statens-tilbud-2022.pdf

NIBIO, The Norwegian Institute of Bioeconomy Research. (2019). Plast på avveie i jord. NIBIO web-page. https://www.nibio.no/nyheter/plast-pa-avveie-i-jord?locationfilter=true

Miller, T. (2013). Constructing sustainability science: emerging perspectives and research trajectories. Sustain Science, 8:279–293. doi:10.1007/s11625-012-0180-6

Natcher, D., Kvalvik, I., Reykdal, Ó., Hansen, K., Govaerts, F., Elde, S., Nøstvold, B.H., Rødbotten, R., Dalmannsdottir, S., Halland, H., Uleberg, E., Árnason, J., Pálsson, P.G., Halldórsdóttir, R., Hilmarsson, Ó.Þ., Þórðarson, G., and Valsdóttir, Þ. (2021). The Arctic as a food-producing region. In Renewable Economies in the Arctic (pp. 249-262). Routledge.

Nøstvold, B. H., Kvalvik, I., Heide, M., Govaerts, F., Hansen, K. B., Dalmannsdottir, S., Halland H., Vøllestad, Å., and Ramstad, S. (2019). Status, verdi og utfordringer for matproduksjon i Arktisk Norge – Rapport 2 "Arktis som en matproduserende region". Nofima Rapport 33/2019, Tromsø.

Reim, W., Dr., Sas, D., Rainosalo, E., Ehimen, E., Murray, L., Lamprinakis, L., and Halland, H. (2020). Report on Existing circular economy cases and their business models. A SYMBIOMA project report. Deliverable T1.1.1.

Schader, C., Baumgart, L., Landert, J., Muller, A., Ssebunya, B., Blockeel, J., Weisshaidinger, R., Petrasek, R., Mészáros, D., Padel, S., Gerrard, C., Smith, L., Lindenthal, T., Niggli, U., and Stolze, M. (2016). Using the Sustainability Monitoring and Assessment Routine (SMART) for the systematic analysis of trade-offs and synergies between sustainability dimensions and themes at farm level. Sustainability 8, 1–20. doi:10.3390/su8030274

UN (United Nations). (2015). Transforming our world: The 2030 agenda for sustainable development. A/RES/70/1. https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

UN (United Nations). (2019). The Sustainable Development Goals Report 2019. https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf

WCED (World Commission on Environment and Development). (1987). Our Common Future. Oxford: Oxford University Press.