HOLISTIC RESOURCE MANAGEMENT FOR
CLIMATE RESILIENCE OF FARMING

Measure Sheets
ClimateFarming

2022-1-DE02-KA220-VET-000090163

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Content:

AGROFORESTRY

multifuncional | timber, fuel, fruits, nuts | small- & large-scale

Description: Agroforesty (AF) is the systematic integration of woody plants on agricultural land. This multifunctional form of land use can induce a variety of positive interactions. The agriculturally produced products are extended by stem wood, energy wood, fruits, nuts or also fodder foliage. Overall, this can lead to an increased productivity.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Drought: Less susceptible to drought conditions (optimized microclimate)

Heat: Lower temperatures in the cultivation (optimized microclimate)

Water: More water in the ecosystem. Irrigation is possible.

Diversification: Can diversicate income and increase economic stability. Often direct marketing.

Ecosystem: Improving biodiversity and robustness of agro-ecosystems

Customizable: Suitable for many locations and farms.

Law: Subsidy and technical law often an obstacle. Case-by-case reviews helpful.

Experience and data: Knowlege-intensive. Currently there is little experience with modern agroforestry systems which leaves space for pioneer work.

Inputs and Invest: Depending on the system, but increasing demand for investment and working time

Path dependency: Reversibility possible but associated with costs and effort

Implementation Example

On 12 ha of the lighthouse farm **Werragut** in Central Germany a trial plot was established on the farm for testing 15 fruit species in combination with different substrates, tree protection systems and irrigation systems. The area is monitored and regular guided tours are arranged. **More Infos: werragut.de**

AGROFORESTRY

Assessment

FIELD LEVEL

Soil: AF can potentially be established on all soils, but the quality of the soil will influence the system's development and attainable yields. Waterlogging greatly limits the possibilities.
Temperature: A high variety of woody perennials are possible and planting times can be adjusted to the temperature. However, the colder the site, the shorter the growing season. Excessive irradiation can be a problem.
Frost: AF is vulnerable to (late) frost events. The systems should be planned accordingly.
Wild animals can cause great damage. There are different protection systems.

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- The positive effect of AF on GHG emissions is well researched
- Increase of soil carbon
- Carbon fixation in woody biomass (above and below ground)
- Renewable resources replace fossil fuels
- Reduced pressure on land (increased productivity per m^2)
- Reduced fossil fuel consumption possible (decreasing fertilization and plant protection)
- Optimized microclimate supports soil properties between woody plants
- Long-term effectiveness

ENVIRONMENTAL IMPACTS

- Highly beneficial for enhancing biodiversity
- Adaptation to climate change
- Soil and (ground)water protection
- Improving the microclimate

SOCIAL IMPACTS

- Provide new and interesting jobs in rural and urban areas
- Improvement of the level of local self-suffiency and food sovereignty
- Can increase joy and contentment about working in agriculture, many young farmers establish AF systems

INVESTMENT AND WORKLOAD

Investment:

- Wide range possible; **Minimum: 1.000-15.000 €/ha, depending on the system and own performance**
- Only occupies small amount of land (low opportunity costs)
- Can be tested with low investment approach and scaled up with time

Path dependencies:
Low risk: land can be converted back but needs money

Workload:

- Knowledge-intensive system: learning, implementation and management
- Labour-intensive system: depending on the system and scale
- Innovative system: interesting for integrating new persons in the farm business

ROBUSTNESS (MALADAPTATION CHECK)

- [x] **Multifuncional**
- [x] **Long-term measure. In some cases over several decades.**
- [x] **No negative externalities**
- [x] **Supports diversification**
- [ ] **Measure can be tested**
- [x] **No increase of dependencies**

Comments:
Depending on the system, a successful outcome for AF is highly dependent on professional planning and advice because it is very knowlege intensive.

SYNERGIES (TOP 4)

Within agroforestry systems, the combination with many other measures on field-scale are possible to provide soil, water and climate protection and further support biodiversity. Here are some examples for possible synergy effects at the farm level:

1. **Local energy supply:** Woody perennials can be planted for thermal use (e.g. woodchip heating).
2. **Compost production:** Biomass from trees/ shrubs can be used for composting which can be given back to the soil for nutrient supply and structural enhancement.
3. **Direct Marketing:** Many products from AF systems like fruits, nuts, berries are great for direct marketing. The positive impact on the landscape and long-term systems also helps to increase customer loyalty.
4. **Biochar production:** Biomass from trees/ shrubs can be used for biochar production.

AGRIPHOTOVOLTAIC

Energy | Diversification | Integrated Land-Use

Description: Agro- or agriphotovoltaic (APV) systems aim at integrating food and energy production on the same piece of land with photovoltaic (Weselek et al., 2019). APV aims at increasing the land productivity due to combined production of food and energy and usage of potential synergistic effects. The overall relevance for adaptation is dependent on the specific system.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Drought: Shading of PV-modules could reduce evapotranspiration

Heavy Precipitation and Hail: Depending on the crop (e.g. fruit shrubs), PV-modules can provide protection

Heat: Shading of PV-modules could reduce heat stress in crops and livestock - but can also reduce crop productivity

Planning: Complicated planning procedure with potential barriers (local administration, public acceptance)

Diversification: Can moderate income losses during drought/heat events - good addition to climate sensitive farm business

Investment: Irrigated APV installations encompass generally a large investment need

IMPLEMENTATION

Hofgemeinschaft Heggelbach: combination of arable crop production and PV:

hofgemeinschaft-heggelbach.de

Overview of running **research projects** and general information concerning APV technology:

https://agri-pv.org/de/

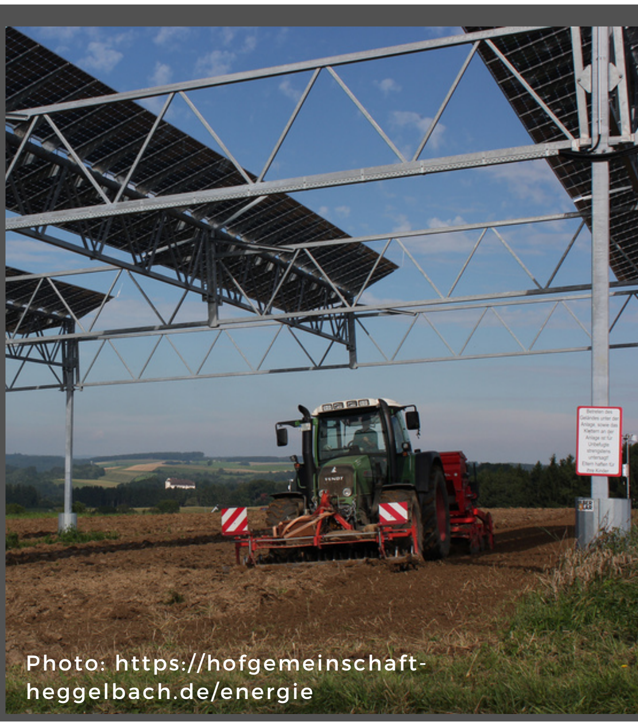

Photo: https://hofgemeinschaft-heggelbach.de/energie

FIELD LEVEL

Soil: APV should be focused on soils with a lower production potential in order to minimize conflicts with food production and optimize productivity of fields with lower soil quality
Sun hours: The higher the number of sun hours in the specific location, the higher the potential yield of the PV installation
Field exposition and sourrounding vegetation: In the best-case, the concerned field is able to catch sunlight during the whole day - however, this is not a neccesary condition for a productive APV system

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- Replacing fossil fuel based energy production
- In case of on-farm usage: provides an incentive to switch to electric vehicles
- Depending on the subconstruction, the installation of APV-systems will entail more GHG-emissions than a comparable installation on a roof or open-field

ENVIRONMENTAL IMPACTS

- The influence on the broader agroecosystem is uncertain and comprehensive research is lacking
- Main positive impact is the reduced land-use due to the integrated production of energy and food
- Room between the mounting poles could be used for the cultivation of hedges or other perennial biomass, what can improve habitat diversity of the agricultural land
- Practice reports show that especially during heat events, the shade of the PV-modules provides shelter for insects and birds

SOCIAL IMPACTS

- Can improve local availability of clean energy, e.g. a charging station for electric vehicles
- APV is a new and innovative concepts which largely changes the aesthetics of the landscape. This could entail disapproval by the local administration or public.

INVESTMENT AND WORKLOAD

Investment:

- **Minimum: ~ 500.000€**
- Rentability of an APV installation increases with scale due to high fix-costs. This makes a certain minimum area/investment necessary.
- Investment costs vary depending on the specific APV system
  - Rule of thumb: the higher the modules must be mounted, the higher the price per kWp installed capacity
- Investment costs are also dependent on the existing infrastructure (e.g. availability of a feed point)

Workload:

- High workload during planning and installation due to partly complicated legislative processes
- After installation, workload is relatively small - but depends on the specific system
- For example, dynamic modules need more maintenance than static modules

ROBUSTNESS (MALADAPTATION CHECK)

- [x] **No-Regret Measure**
- [ ] **Reversible and flexible**
- [ ] **Reduced time horizon**
- [x] **No negative externalities**
- [x] **Supports diversification**
- [ ] **Measure can be tested**
- [x] **No increase of dependencies**

Comments:

APV entails high investment costs and is only reversible in the mid- to long-term. This will partly impair the financial felxibility of the farm. However, APV is not sensitive to climatic changes and can provide a stable and reliable income source, which largely reduces its potential to be maladaptive.

SYNERGIES (TOP 3)

1. **Fruit Production:** Certain permanent crops (especially berries) grow better when partly shaded
2. **Energy intensive farms:** The production of on-farm energy can largely decrease energy costs and vulnerability to network failures
3. **Rainwater harvesting:** APV-modules can also be used to collect rainwater. However, the sufficient wtaer-supply of the crops beneath the modules must be ensured

COVER CROPS

Carbon farming | Soil management | Crop rotation

Description: Cover crops are a form of crops integrated in a crop rotation. Their main goal is to create a soil cover preventing bare soil (f.ex., between growing seasons). Their compositon out of different species serves to improve the soil, by diminishing weeds, controling diseases and pests, increasing biodiversity and increasing water uptake (water absorption capacity). Cover crops help to limit erosion and nutrient loss and in combination with leguminous species even add to the nutrient balance.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Climate resistance: Soil is less susceptible to drought conditions , helps increasing water holding capacity

Soil and fertility management: Promotion of soil life, increase in infiltration capacity and erosion protection

Pest management: Cultivar choice, placement and timing of cover crops can reduce infestations by insects, diseases, nematodes and weeds

Ecosystem service: Various different seed mixtures and varities are added to the crop rotation. Offering needed habitat for many species

Sun: Utilises the full photosynthetic potential of a field

Knowledge and research: A thorough understanding of cover crops and the relation and benefits of different species in regard to the soil and it's proprieties are needed

Implementation: Wrong implementation practices may lead to increased passage of machinery on the field, leading to soil compaction and fuel usage

Inputs/ Workload: Needing more workforce and time to add another culture to the farm production

Implementation Example

The **Oekozenter** leads a trial with 5 different cover crop species to demonstrate implementation and development of different mixtures and varieties in the condition of Luxemburg.

COVER CROPS

Assessment

FIELD LEVEL

Soil: Effective soil conservation practice by reducing runoff and water erosion. Cover crops raise soil fertility, increase soil organic matter and raise the aggregate stability of the soil.
Fertilization: Adding leguminous species to the cover crop mixtures allows to fix atmospheric nitrogen in the soil due to their root's capacity through the symbiotic relation with bacteria. Incorporation of cover crops after growing season functions as green manure.
Pests and diseases: Covering bare soil with cover crops provides direct competition to weeds. And adding various species to the crop rotation limits diseases and pests.
Frost events: A distinction is made between overwintering and freezing off, the choice should be made on the basis of the following crop and planned soil cultivation.
Crop rotation: If, for example, oilseed rape is part of the crop rotation, crucifers should not be used as catch crops.

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- Cover crops absorb CO_2 and store carbon in the soil
- Sustainable agricultural practices combined with cover crops reduce the emissions of vehicles used in soil management.

ENVIRONMENTAL IMPACTS

- Raising soil's ability to absorb intense rain events, holding moisture.
- Increase organic matter, improving the soil structure preventing soil erosion.
- Breaking pest, disease and weed cycles.
- Providing diverse species on generally bare soils, creating a habitat for a multitude of species and promoting soil life.

SOCIAL IMPACTS

- Diverse crops with flowers present a better image than bare soil.

COVER CROPS

Assessment

INVESTMENT AND WORKLOAD

Investment:
- **150-300 €/ha**
- Costs are limited in the seeds, manpower and fuel/machinery.
- Main investment is time and work, during a busy period.
- Low risk: land will not be influenced negatively by the implementation of cover crops.

Workload:
- Knowledge-intensive system: The right crops and varieties must be found in regard of the soil proprieties and the crop rotation.
- Not very much time consuming only need planting once and either yielding or mulching once.

ROBUSTNESS (MALADAPTATION CHECK)

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Comments:

Depending on the soil, cover crops is highly dependent on the encountered conditions and the benefits wanted. A wide variety of seeds can be adjusted to fit every scenario.

COVER CROPS

Assessment

SYNERGIES (TOP 3)

1. **Reduction of fertilization:** Due to the characteristics to enhance soil fertility, less fertilization is needed.
2. **Crop rotation:** Additional element in the crop rotation reduces weed, pest and diseases pressures.
3. **Soil properties:** Cover crops enhance soil structure, health and overall quality. Raising the growing potential of following crops.

FURTHER INFORMATION

https://www.fabulousfarmers.eu/en/get-fabulous/fab-measures/begruenung

FIELD BLOCK OPTIMIZATION

Economic efficiency | Lower soil compaction | Ecological stability

Description: Field block optimization (FBO) is one of the approaches of precision agriculture. The goal is to design the optimal shape and size of the land block resulting in the establishment of productive and non-productive areas that serve environmental-technical-social purposes. The correct shape and size of the soil block saves time, fuels, fertilizers and seed. And it also reduces soil compaction through mechanization.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Ecosystem: Non-production areas increase ecosystem stability, retain water and increases biodiversity. Reduction of water and wind erosion.

Legislation: Absence of assessment of benefits and non-production functions of environmentally technical areas in legislation.

Prevention: Of soil compaction by mechanization.

Duration: Time consuming preparations.

Inputs: Consumption of fuels, fertilizers, seeds and time is reduced.

Consultancy: Lack of counseling support.

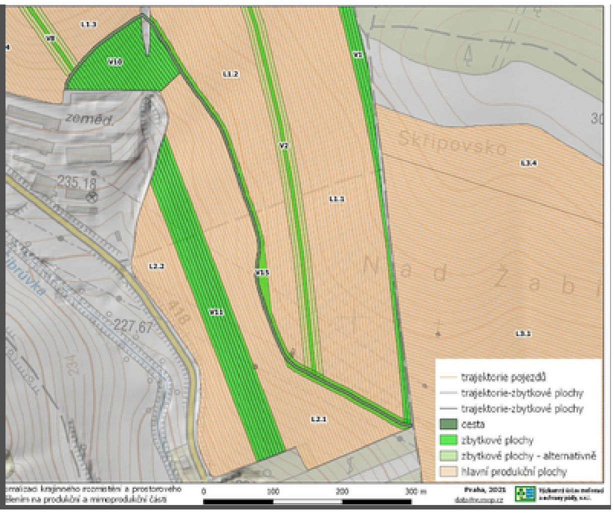
Time savings: More efficient crossings after optimizing crossing trajectories.

Investment requirement: To achieve the maximum effect, the use of a satellite navigation system is necessary.

Implementation Example

One of the example locations is EKOFARMA PROBIO Velké Hostěrádky (Czech Republic). The farm operates in an organic farming system approximately on 360 hectares of arable land, where the vast majority of land consists of areas at risk of erosion. Field block optimization helps reduce the risk of erosion.

https://www.ekofarmaprobio.cz/



FIELD BLOCK OPTIMIZATION

Assessment

FIELD LEVEL

- Increasing the efficiency of agrotechnical operations based on optimizing the shape and size of production parts.
- Elimination of technogenic soil compaction on vulnerable production areas.
- Creation of framework conditions for the full application of navigation systems.
- Increasing the competitiveness of plant production even while ensuring non-production functions of agriculture.
- Increasing the permeability of the landscape for equipment ensuring the maintenance of distribution networks, roads, etc.

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- Reduces GHG emissions because of lower fossil fuel and fertilizer consumption
- Reduces soil compaction (increased productivity per m^2)

ENVIRONMENTAL IMPACTS

- Elimination of erosion, soil compaction, and reduction of nutrient losses.
- Increasing the ecological stability of the landscape.
- Limitation of greenhouse gas production.
- Stabilization of the energy balance.
- Reduction of the import of substances used in agricultural production.
- Supporting food chains and migration routes.
- Connection of stable components of the landscape matrix.
- Increasing the water retention potential of the landscape.
- Protection of water bodies, reducing the risks of eutrophication and silting with sediments.

SOCIAL IMPACTS

- Prevention of material damage to property (flooding).
- Increasing the permeability of the landscape for leisure-time purposes of the public in nature.
- Targeted action to change the landscape character and support the aesthetic appearance of the landscape.
- The emergence of transition zones between agricultural production and other parts of the landscape.

FIELD BLOCK OPTIMIZATION

Assessment

INVESTMENT AND WORKLOAD

Investment:

- **Consultancy: 15-30 € /ha designing**
- It is recommended to contact experts to achieve optimal settings
- **Satellite navigation system: 10 000 - 25 0000 €**
- It is recomended use satellite navigation system to achieve maximum efficiency
- Can be tested on the part of soil blocks but when satellite navigation system is used, is better to have more optimized soil bloks
- Main investment is time which is important for good site analysis

Workload:

- Expert-intensive system: for a good setting and quality site analysis experts are needed
- Knowledge-intensive system: learning with satellite navigation system can take up an amount of time
- Innovative system: interesting for streamlining work processes and saving the costs

ROBUSTNESS (MALADAPTATION CHECK)

- [x] **No-Regret Measure**
- [ ] **Reversible and flexible**
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Comments:

The measure (SBO) makes it possible to effectively set aside parts of land for Environmental-Technical Areas. These areas support diversity, retain water and create a more stable ecosystem.

FIELD BLOCK OPTIMIZATION

Assessment

INVESTMENT AND WORKLOAD

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FURTHER INFORMATION

Comments:

The measure (FBO) makes it possible to effectively set aside parts of land for Environmental-Technical Areas. These areas support diversity, retain water and create a more stable ecosystem.

FIELD BLOCK OPTIMIZATION

Assessment

SYNERGIES (TOP 3)

1. **Environmental-Technical Areas + agricultural land:** effective division of land will make it possible to set aside part of the land to ensure environmental functions
2. **Lower vulnerability:** FBO will reduce the land's susceptibility to water and wind erosion, as well as soil compaction
3. **Costs:** optimization will bring cost savings - lower consumption of fuels, fertilizers, seeds

IMPLEMENTATION PLAN

How to implement this measure:

1.Site analysis
Identification of critical sites from the point of view of water and wind soil erosion, inclination, susceptibility to consolidation, slope variability and analysis of existing documents such as land use plan, etc. Analysis of geometric characteristics.

2. Field block optimization
Optimizing the shape and size of plots, availability to the plot, optimizing crossings and transplanting and implementing other principles of precision agriculture and quantifying their benefits.

3. Draft measures
Agrotechnical and organizational recommendations. Evaluation of DZES conditions. Design of crop structure and design of sowing and management of environmental-technical areas.

4. Digitization
Digitization of all underlying layers and land block optimization proposals, including land raids into an online browser or LPIS.

FIELD MARGINS

(HEADLAND, HEDGEROWS, FLOWERING STRIPES)

Field structure | Crop Production | big scale

Description: Field margins (Headlands....) and other non-crop vegetation structures in agriculture respond directly to climate caused challenges. These covered surfaces are limiting soil erosion and enhance water absorption. Additionally, headlands and field margins play an important ecosystem role (pest regulation, pollination and nutrient cycle) as well as enhancing biodiversity and creating habitat for a multitude of animals.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Eroision: Covered soil and enhanced soil structure lead to reduced soil erosion. Protection of the bare soil.

Flooding + Water erosion: Field margins located at strategic locations, at the end of a field slope and near waterflows can avoid flooding and contamination of waterways

Connectivity: Field margins act as ecological corridors, supporting habitat restoration

Ecosystem: High diversity of plants - improving biodiversity and robustness towards pests and diseases

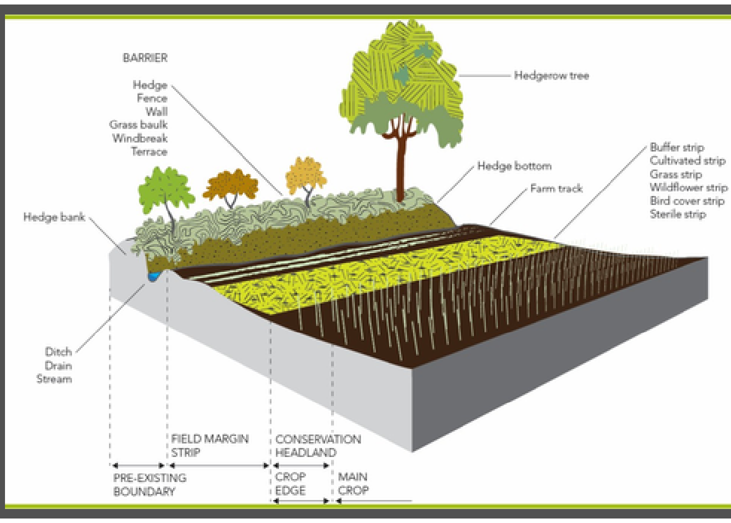
Environmental pressures: Headlands can promote weed infestations, disease induction and pest infestations.

Outputs/production: Less area can be cultivated, reducing overall production

Inputs: Reduces use of herbicides, pesticides and fungicides. It creates multiple habitats and promotes pollination.

Health: increases well-beeing, as part of recreation

Implementation Example:
Field margins can be found in numerous different forms with related specific ecological benefits for fauna and flora. Additionally at the right location field margins take part in the adaptation of the agricultural practices to climate change.



FIELD MARGINS

Assessment

FIELD LEVEL

Soil: Multifunctional field margins increase soil abundance and less invasive crop management systems in general increase survival and thriving of soil organisms. Therefore soil structure and fertility are improved and promoting soil pore structure, soil aggregation and the decomposition of organic matter.
Important: use a seed composition of native species.
Water: Perennial field margins play an important role in preventing water pollution, and water erosion combined with flood attenuation and water retention by regulating the capture, infiltration, regulation, retention and flow of water across landscapes.
Temperature and Frost events: With regard to flowering field margins, it is important whether a perennial or annual flowering strip is planted. Perennials should be sown in autumn and annuals in spring. In the case of spring sowing, this should be done early in order to be attractive to beneficial insects but not to suffer frost damage.

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- Carbon sequestration potential increases with increasing margin width and depends on plant diversity
- Increases soil health
- Reduced input and fossil fuel consumption
- Can create windbreaks, reducing wind speed, therefore lowering the risk of wind erosion
- High genetic diversity allows faster adaptation to climate change
- Reduces flood risks and nutrient run-off into water bodies

ENVIRONMENTAL IMPACTS & ECOSYSTEM SERVICES

- Field margins promote genetic diversity,
- Pools for pollinating and pest controlling species.
- Multifunctional field margins increase soil abundance of soil macro fauna, including earthworms, woodlice and beetles.
- Food source and nesting site for mammals and birds.
- Creating migration corridors between biodiversity hotspots.
- Reduces use of herbicides and pesticides
- Promotes rare native plants

FIELD MARGINS

Assessment

SOCIAL IMPACTS

- Farms can better promote their produce, field margins are visually pleasing for costumers.
- Field margins may be combined with recreational opportunities and tourism.

INVESTMENT AND WORKLOAD

Investment:

- Mechanical soil cultivation and seeding 100-200 €/ha
- Mechanical cutting with or without salvage of the cut material 40-100 €/ha
- Seeds: 40-700 €/ha
- Main investment is the loss of productive area
- Low risk: land can be converted back to arable production (laws may vary between countries)

Workload:

- Easy to understand and little knowledge needed
- Minimal and occasional work needed
- Good implementation in function of criteria (location, problems, waterfloods, biodiversity, connectivity...)
- Visual measure, easy to communicate to population

ROBUSTNESS (MALADAPTATION CHECK)

- ✔ **No-Regret Measure**
- ✔ **Reversible and flexible**
- ✔ **Reduced time horizon**
- ✔ **No negative externalities**
- ✔ **Supports diversification**
- ✔ **Measure can be tested**
- ✔ **No increase of dependencies**

Comments:

The correct implementation depends on a lot of different criteria, including diversity of species, topography of the field, crop produced in the field. But the measure is easy and fast to implement and can bring a lot of benefits for a small investment.

FIELD MARGINS

Assessment

SYNERGIES (TOP 3)

1. **Pollinated crops:** FM create areas with high count of pollinators, essential for the pollination process of a large number of crops.
2. **Extensive agriculture :** Auxiliary insects provide functions in pest management, no pesticides needed if FM are correctly placed.
3. **Agroforestry:** Integration of trees and shrubs can be essential in field margins installed in flooding areas.

HOW TO IMPLEMENT THIS MEASURE:

- IDENTIFICATION OF LOW YIELDING AREAS IN FARMS, CAN BE PLACED ALONG HEDGES, BANKS, FOREST FRINGES, DITCHES AND WATER COURSES.
- FIELD MARGINS ARE LONG-TERM STRUCTURAL ELEMENTS OF A FARM. BEST INTEGRATED WHEN CONNECTING ECOLOGICAL INFRASTRUCTURES.
- PREPARATION: PREPARE SEED BED, SOWING AND MANAGEMENT IN THE FIRST YEAR WITH CUTTING/MOWING TO LIMIT ANNUAL WEEDS AND PERMIT DEVELOPMENT OF FLOWERS AND SOWN SEEDS.
- MANAGEMENT IN FOLLOWING YEARS: CUTTING THE MARGINS 50% EVERY YEAR AT THE END OF THE FLOWERING SEASON, ALTERNATING EVERY YEAR TO GUARANTEE OVERWINTERING HABITAT FOR SPECIES.

SOURCE: MFFM-ASSESSING-THE-BENEFITS-FOR-NATURE-SOCIETY-AND-BUSINESS.PDF (SYNGENTA.COM)

FURTHER INFORMATION

MFFM-Assessing-the-benefits-for-nature-society-and-business.pdf (syngenta.com)

https://www.fabulousfarmers.eu/en/get-fabulous/fab-measures/field-margin-management/webinars-5

GREEN MANURE

Soil protection and improvement | Organic matter | Nitrogen

Description: There are many reasons why to implement green manure into the sowing processes. From improving soil quality to nitrogen fixation. For farm without cattle is the green manure the best solution how to nourish the soil and to produce organic matter. There are many types seeds and mixtures. Farmers have to decide what they want to achieve. It is possible to use a mixture with grasses if the green manure is used for fodder.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Soil improvement: green manure is a carbon that breaks down quickly. The main function is to feed microorganisms, mainly bacteria, and provide a quick flush of nutrients to soil life and the next crop.

Easy implementation: if you follow the basic recommendations.

Soil protection: against the erosion, heat and frost, lower evaporation.

Biodiversity support: habitat for pollinators and wild animals.

Recommendation: it is necessary to choose a suitable mixture of seeds for the chosen purpose

Climate problem: Green manures that are incorporated after they have been killed by frost, or those that are rich in biomass and winter-hardy, can release more climate-damaging gases (especially nitrous oxide) into the atmosphere during freezing and thawing cycle in winter.

Inputs: incidental costs are needed (seeds, cultivation)

Implementation Example

One of the example locations is EKOFARMA PROBIO Velké Hostěrádky (Czech Republic). The farm operates in an organic farming system approximately on 360 hectares of arable land, where the vast majority of land consists of areas at risk of erosion. They use green manufe for erosion protection and for improving soil structure.

https://www.ekofarmaprobio.cz/

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- reduction of evapotranspiration due to soil cover

ENVIRONMENTAL IMPACTS

- Elimination of erosion during the winter season
- Soil protection against the heat or frost
- Increasing the water retention
- Nutrition for the soil organisms and bacteria
- Impact on increasing of insects, pollinators and wildlife

SOCIAL IMPACTS

- Prevention of material damage to property (flooding).
- Maintaining or improving soil quality = property quality

INVESTMENT, WORKLOAD AND FIELD LEVEL

Investment:

- Seeds, fuel, time and mechanization for sowing

Workload:

- It is important to choose appropriate plants (seeds, mixtures) for your objective:

1. **Improving of the soil structure - production of organic matter**

- For this reason is the best solution grass-clover mixtures which will grow on the field at least 1,5 years. Their roots grow through the soil deep and intensiv. Regular mowing is recommended. The last mowing can be processed into mulch. Cattle-free farms can use lucerne-clover mixtures. But include grasses is an advantage. Grasses are better in organic matter production and have more stable release of nitrogen.

GREEN MANURE

Assessment

2. Erosion protection during winter

- To protect the soil against erosion is recommended the timely seeding of winter-hardy green manure. Grass-clover mixture, ryegrass after cereals, forage rye, vetch rye, winter turnips after potatoes or maize.

3. Nitrogen supply for following crop

- Legume crops are the best nitrogen suppliers (peas, field beans, clover-lucerne mixtures). During the long term dense cultivation (left standing until flowering) they can furnish 70-140 kg nitrogen per hectare. For a shorter cultivation period is summer vetches or Egyptian-Persian clover suitable. Grain legumes (lupine) are able to bind phosphorus.

4. Conservation of nitrogen for the following crop

- For nitrogen conservation is recommended to use fast growing plants like green oats, forage rye, mustard, turnip and oil (fodder) radish. They are also tested new fast growing and drougt-resistant varieties of crops like Sudangrass and lyme grass.

5. Subsoil loosening

- For this purpose it is needed deep-rooting plants. It can be used oil (fodder) radish, perennially cultivated lucerne, lupines, field beans. It is recommended to loosen the soil with cultivator before the sowing. The plants may access the deeper soil layers more easily. Cultivation period is recommend at least 3 months.

6. Prevention of pests and deseases

- The main recommendation for prevention of pests and diseases is not to cultivate the green manure that is closely related to the main crop (e.g. mustard with rapeseed).

7. Weed supression

- For suppressing of seed-propagated weeds it is needed fast growing green manures which are amenable to a cut soon after growth to 10-15 cm in height and than they form a densely closed stand. For suppressing of perennial weeds it is needed to use perennial stands of grass-clover.

GREEN MANURE

Assessment

PLANTS AND THEIR EFFECT

Green manures and their effect

Green manure/ mixture	Production of organic matter	Gain of nitrogen for following crop	Subsoil loosening	Erosion protection during winter	Prevention of pests and diseases [1]	Weed suppression	Comments
Grass-clover 1,5 years	●●●○	●●●○	●●○○	●●●●	●○○○	●●●○	Suppresses thistles and bindweed, promotes docks/sorrels. Risk of wireworms for following crop. Thorough rooting of the deeper soil with lucernes.
Pure grass seeds (up to 9 months)	●●●○	●○○○	●●○○	●●●○	●●●○	●●●○	Non-host for root-knot nematodes and many crop-rotation diseases of root crops and vegetables.
Clover-lucerne mixture (up to 9 months)	●●●○	●●●●	●●●○	●●●○	●○○○	●○○○	Suited as a green manure between cereals and maize, little 'depth effect' given an over-year-long cultivation. Longer periods of cultivation maybe applicable.
Lupines, field beans (until flowering)	●○○○	●●●●	●●●○	●○○○	●○○○	●○○○	Susceptible to nematode varieties, few problems with wireworms in following crop. Lupines need warmth. Rather unsuitable when legumes are part of the main crop.
Peas, vetches (until flowering)	●○○○	●●●●	●○○○	●○○○	●○○○	●●○○	Pea is less warmth-dependent, also suitable for winter cultivation. Vetches depending on type. Peas are unsuitable if the same are part of the main crop. Vetches only limitedly.
Phacelia (until flowering)	●○○○	●○○○	●○○○	●○○○	●○○○	●●●○	Not related to crop types. 'N-gain' via prevention of washing out.
Oil (fodder) radish	●○○○	●○○○	●●●○	●○○○	●●●○	●●●○	Not in a crop rotation with cruciferous plants, subsoil loosening only when cultivated for a longer period. 'N-gain' via prevention of washing out. Recovery effect depending on variety (nematodes).

Key: ○○○○ no effect; ●●●● = very strong effect; [1] Focus on diseases with a wide range of hosts, and nematodes

MARKET GARDENING

Diversification | Vegetable Production | Small-Scale

Description: Market gardening (MG) is a novel concept in agriculture, mainly focused on high-value cash crops (vegetables). MG employs a small amount of land, uses direct-marketing channels and cultivates a high variety of plants while minimizing mechanization and financial investment needs.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Drought: Less susceptible to drought conditions (irrigated system)

Heat: Vegetables are planted set-wise - can be adjusted to changed patterns. Heat waves in spring can be problematic (early flowering)

Diversification: Can complement existing production structures but dependent on direct marketing

Ecosystem: High diversity of plants - improving biodiversity and robustness towards pests and diseases

Heavy Precipitation and Hail: Ususally open air production - susceptible to heavy rain and hail events

Health: Constant exposition to heat and sunlight can cause health issues and impair productivity

Water: Irrigated system - need to secure sustainable supply of irrigation water

Inputs: Depending on the soil, MG is highly dependent on the availability of high quality compost

Implementation Example

On the **Hof Tolle**, all production branches were susceptible to drought . The irrigated vegetable production can balance losses in drought periods. The market gardening was established by two external persons which were interested in the Market Gardening system - **more Infos: hof-tolle.de**

FIELD LEVEL

Soil: MG can potentially established on all soils, but the quality of the soil will influence the amount of compost needed to establish the vegetable beds
Temperature: A high variety of vegetables are deployed and planting times can be adjusted, the temperature. However, the colder the site, the shorter the growng season
Frost events: MG is vulnerable to (late) frost events. Cultivars selection should be planned accordingly. Various protection measures exist

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- The effect of MG on GHG emissions is not well researched yet
- Reduces pressure on land (increased productivity per m^2)
- Reduced input and fossil fuel consumption
- Indirectly, the availability of local, high-quality vegetables could increase the consumption, which in turn could reduce the consumption of other products, which produce higher GHG emissions
- Uncertain factor: GHG-emissions of compost production

ENVIRONMENTAL IMPACTS

- Depending on the design of the MG, the production mode can be highly beneficial for enhancing local biodiversity and improving the microclimate
- Higher availability of local food can reduce need for import and indirectly reduces negative impacts of intensive production systems in other parts of the world
- Potentially negative is the usage of plastic foils and nets for plant protection and the consequent

SOCIAL IMPACTS

- MG can provide new and interesting jobs in rural and urban areas
- Improvement of the level of local vegetable self-suffiency and food sovereignty

MARKET GARDENING

Assessment

INVESTMENT AND WORKLOAD

Investment:

- **Minimum: <1.000€**
- Only occupies small amount of land (low opportunity costs)
- Can be tested with low investment approach (< 1.000€ is possible) and easily scaled up with time
- Main investment is time and work
- Higher investments will be necessary if production is complemented by greenhouse production
- Low risk: land can be converted back to arable production, active market for used tools and tunnels

Workload:

- Knowledge-intensive system: learning and implementation will take up a high amount of time
- Labour-intensive system: depending on the system and scale, labour-cost can constitute 75-90% of the overall costs
- Dependent on direct-marketing channels: due to higher prices compared to conventional vegetable production, direct marketing will be in most cases necessary
- Innovative system: interesting for integrating new persons in the farm business in order to reduce workload

ROBUSTNESS (MALADAPTATION CHECK)

- ✔ **No-Regret Measure**
- ✔ **Reversible and flexible**
- ✔ **Reduced time horizon**
- ✔ **No negative externalities**
- ✔ **Supports diversification**
- ✔ **Measure can be tested**
- ○ **No increase of dependencies**

Comments:

Depending on the soil, MG is highly dependent on the avaiability of high quality compost. Diversification of sourcing or internal compost production should be considered

SYNERGIES (TOP 3)

1. **Rainwater Harvesting:** MG is dependent on irrigation - need to secure sustainable water supply
2. **Composting:** Main input for MG - producing on-farm compost could make the farm more independent from external sources
3. **Agroforestry:** Integration of trees and shrubs can improve natural regulation mechanisms (pest and diseases) in MG and enhance the variety of products

REDUCED TILLAGE

Erosion Control | Soil Structure | Arable Cropping

Description: Reduced or no tillage (often referred to as/ similar to no-till, zero tillage, minimum tillage, conservation tillage or direct drilling) practices have the goal of reducing soil disturbance during field operations like weed management or seeding. Crop residues are left on the soil surface as mulch. Tillage has adverse effects on soil organic matter, soil structure and other environmental factors. Reduced or no tillage can be paired with cover cropping and crop rotations for best results.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Water storage: Reduces soil water loss by evaporation or runoff from the soil surface.

Water infiltration and quality: Can improve water infiltration and retention. Can improve water quality adjacent to agricultural land. However, if not implemented well, can also cause compaction.

Soil erosion and nutrient loss: Reduces soil loss by water and wind. Also decreases nutrient losses and pesticide leaching from surface runoff.

Soil organic matter (SOM): May contribute to increased amounts of SOM in top soil, and with it soil carbon levels.

Soil life: Increases diversity and amounts of soil fauna like earthworms, which have positive effects on soil quality.

Economics: Saves labour and fuel required to power machinery during tillage operations.

Soil structure: Can prevent soil compaction caused by heavy machinery. However, if not implemented well, can also cause compaction.

Weeds: No weed control through tillage. Often, herbicides are used instead, but alternative options exist.

Pests and diseases: Crop diseases can be harbored in surface residues. Pests that need additional management may arise.

Complexity: May require more complex ecosystem management to increase predator populations and improve biological pest/disease control.

Implementation Example:
No-till in organic agriculture: Werragut

- Shallow full-surface soil cultivation
- Clover and diverse cover crops in crop rotation
- Machine options: cultivator, rotary tiller, disc plow, power harrow
- Challenges include weed pressure, mineralization in spring

REDUCED TILLAGE

Assessment

FIELD LEVEL

Soil type: The benefits of reduced tillage depend on the soil type and are highest in well-drained coarse or medium-textured soils, i.e. sandy and loamy soils. Excessive tillage can lead to poor aeration and water infiltration. Sandy soils are prone to soil structure depletion.

Soil moisture and temperature: In regions with cold temperatures in spring, poorly drained soils potentially warm up slower without tillage. This may result in delayed planting. However, conventional tillage destroys soil structure, leading to decreased aeration and water infiltration which reduces resilience in terms of flooding and droughts in the long term.

Occasional or strategic tillage: Eliminating tillage in the long term may result in a compaction layer which can be broken by so-called sub soiling every 5-10 years. This practice is also referred to as occasional or strategic tillage and may also be helpful for weed management, incorporating soil amendments like lime, manure or crop residues, or transporting SOM to greater depths.

Occasional tillage does not usually have large negative effects on soil properties and productivity that have been built up by no-till, if well-planned. It is however important to simultaneously establish a cover crop with strategic tillage to avoid erosion [5].

Soil life: Soil disturbance through tillage harms soil micro- and macrofauna, and thus reducing it will increase their abundance and diversity, which in turn supports plant growth. For example, earthworms are essential builders of soil structure and digersters of nutrients and their abundance is directly correlated with higher soil fertility. Introducing beneficial insects and other animals can help fight pests and diseases, e.g. lady beetles to eat aphids.

REDUCED TILLAGE

Assessment

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- Reduced fossil fuel consumption.
- Reduced carbon losses from soils.
- The amount of additional SOC unter no-till is relatively small and often overestimated. Apparent increases in SOC result from altered depth distribution [1], as no-till often simply avoids the mixing of higher C topsoil with deeper soil layers. SOC increases in the uppermost soil layers with no-till, but these gains are offset by decreases of SOC in deeper soil layers. The C sequestration potential of no-till with respect to climate change is thus likely to be overvalued [2]. However, a larger C concentration in the topsoil following no-till is generally favourable for other soil properties that translate into better crop growth [1].

ENVIRONMENTAL IMPACTS

- Use of herbicides instead of mechanical weeding, leading to negative impacts on soil biodiversity and the surrounding environment, e.g. decreasing earthworm populations. However, reduced or strategic tillage can also be employed in organic farming systems.
- Less nutrient leaching and pesticide run-off from bare soil.
- Increased soil fauna and habitat for birds [1].
- Improved overall soil quality, resulting in higher climate adaptation and food security.

SOCIAL IMPACTS

- Lower workload.
- Lower costs of machinery use.

REDUCED TILLAGE

Assessment

INVESTMENT AND WORKLOAD

Investment:

- Initial cost for special equipment needed for mechanical weed control or direct seeding machines. Large market for used equipment.
- Costs can be alleviated over time through labour and fuel savings, possibly old tillage machinery can be sold. Some sources also claim increased yields.
- Low risk: land can be converted back to conventional tillage.

Workload:

- Employing reduced or strategic tillage may necessitate a more holistic rethinking of field management to counteract the emergence of weeds, pests and diseases and soil compaction or soil hardening by farm machinery traffic.
- Soil microbiota that improve plant defenses, encourage colonization of beneficial predators and parasitoids, and reduce pest abundances and the need for insecticides can be encouraged through no-till combined with crop rotations, pest-resistant crop varieties, adjustment of planting and harvest dates, retention of crop residues, and intercropping [3].
- Compaction can be alleviated by subsoiling in combination with cover crops, diversified crop rotations and controlled traffic [4].

ROBUSTNESS (MALADAPTATION CHECK)

- [x] **No-Regret Measure**
- [x] **Reversible and flexible**
- [ ] **Reduced time horizon**
- [x] **No negative externalities**
- [ ] **Supports diversification**
- [x] **Measure can be tested**
- [x] **No increase of dependencies**

Comments

Dependencies may arise if specific machinery is aquired. However, many machines can be borrowed and the second hand market is usually good.

REDUCED TILLAGE

Assessment

SYNERGIES (TOP 3)

1. **Cover cropping:** To provide mulching material and supress weeds, to protect the soil surface in times when no crop is grown, to decrease erosion and water evaporation, to fertilize, to stabilize/ prevent compaction after occasional tillage.
2. **Diversified crop rotations:** For soil fertility management, pest and disease control.
3. **Controlled traffic:** To prevent compaction.

FURTHER INFORMATION/ SOURCES:

[1] Soil Association (2018): To plough or not to plough. Tillage and soil carbon sequestration. https://www.soilassociation.org /media/17472/to-plough-or-not-to-plough-policy-briefing.pdf

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[3] Murrell, E.G. (2020). Challenges and Opportunities in Managing Pests in No-Till Farming Systems. In: Dang, Y., Dalal, R., Menzies, N. (eds) No-till Farming Systems for Sustainable Agriculture. Springer, Cham. https://doi.org/10.1007 /978-3-030-46409-7_8.

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[5] Wortman, C. (2020): Strategic Tillage for the Improvement of No-Till Cropping Systems. https://cropwatch.unl.edu /2020/strategic-tillage-improvement-no-till-cropping-systems (last access: 27.2.23)

UNDERSOWING

Increasing the resilience of agricultural systems | Environment

Description: Undersowing is a process where a second crop is sown together with the main crop or the second crop is sown when the main crop is bigger. The reason why is the second crop sown is erosion control, improving the health of the soil, improving the soil retention capacity, weeds regulation, reduction of pests and deseases, increasing biodiversity and more benefits for the farmers and environment.

ADAPTATION, VULNERABILITY AND UNCERTAINTY

Soil: improving of soil structure, retention capacity, soil organic matter increasement.

Prevention: of soil erosion, soil compaction, weeds, insetcs and deseases.

Mechanization: adjustment of sowing machines is necessary.

Fertility: It can bind atmospheric nitrogen to the soil or bind excess nitrogen from the previous crop to the biomass of the catch crop.

Investing into the future: healthy soil → healthy agricultural system. Undersowing and catch crops increase the profitability of the main crops.

Aditional costs: seeds of plants for undersowing, fuels, time.

Implementation Example

One of the example locations is EKOFARMA PROBIO Velké Hostěrádky (Czech Republic). The farm operates in an organic farming system approximately on 360 hectares of arable land, where the vast majority of land consists of areas at risk of erosion. Undersowing helps reduce the risk of erosion.

https://www.ekofarmaprobio.cz/

UNDERSOWING

Assessment

FIELD LEVEL

There are two option when to implement undersowing:

- sowing together with the sowing of the main crop (narrow-row crops)
- sowing after the main crop is bigger (broad-row crops)

It is important not to sow deeply (1-2 cm).

Undersowing is used to control the **soil erosion**. Broad-row crops are particularly susceptible to water and winter erosion. Cover crops in maize can serve as a protective layer/mat for the soil during harvest. Maize is usually harvested later in the season when the soil is wet and prone to compaction by heavy machinery and cover crops can **protect the soil from compaction**. Undersowing is also recommend for the cereals.

Another advantage of underseeded cover crops is the ability to **nourish the soil** after the flowering of the cash crop (especially cereals). At this stage, the cash crop transfers most of its energy to grain production, which limits the flow of sugar to the roots. The roots stop producing root exudates that normally feed soil microorganisms. Cover crops can subsidize cash crops and nourish soil biology to maintain high activity. Grasses are exceptionally good at this, but clover can provide more nitrogen to the soil.

Crops from the **leguminous grou**p are able to use atmospheric nitrogen with the help of symbiotic fixation. This includes, for example, red clover, purple clover, sown alfalfa, Pannonian vetiver or bushy vetch, peas, lupine and broad beans. Annual species are capable of binding 50 to 200 kg/ha of organic nitrogen per year. Perennial species such as clover and lucerne can set up to 300 kg/ha per year. It is one of the most important sources of nitrogen in the ecological farming system.

Crops that are **unable to bind atmospheric nitrogen** include rye, oats, triticale, grasses - for example ryegrass; buckwheat, safflower, sunflower, sorghum, mustard and other cruciferous vegetables.

UNDERSOWING

Assessment

This is a group of crops that are used to capture available nutrients in the soil, reduce soil erosion, suppress weeds and produce a high volume of biomass that can contribute to the formation of soil organic matter. If there is a surplus of nitrogen on the land after the main crop has been harvested, catch crops sown in autumn are able to bind 15 to 30 kg of residual nitrogen per hectare. If a catch crop is sown in the summer after the main crop, the catch crops are able to fix up to 75 kg of residual nitrogen per hectare, taking into account previous organic nitrogen fertilization management.

MITIGATION, ENVIRONMENTAL AND SOCIAL IMPACTS

MITIGATION

- reduction of evapotranspiration due to soil cover

ENVIRONMENTAL IMPACTS

- Elimination of erosion during the winter season
- Soil protection against the heat or frost
- Increasing the water retention
- Nutrition for the soil organisms and bacteria
- Impact on increasing of insects, pollinators and wildlife

SOCIAL IMPACTS

- Prevention of material damage to property (flooding).
- Maintaining or improving soil quality = property quality

INVESTMENT AND WORKLOAD

Investment:

- Seeds, fuel, time and mechanization for sowing

Workload:

- It is important to choose appropriate plants (seeds, mixtures)