Potential of poplar plantation for enhancing Polish farm sustainability

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Abstract

Farm sustainability depends on policy that is able to protect natural resources while being open to the market. Traditional crop pressing on natural processes creates an open input-output unstable system. Farming situated in a postglacial landscape cannot counteract erosion and does not engage in all natural resources. The poplar stand has an ability to renew the soil system and assimilate the surplus of mobile substances. This paper presents a proposal to combine poplar with a traditional crop to make the biosystem able to engage in all resources to develop efficient production while making the system more stable. The concept is related to the results of the investigation carried out on farms dealing with typical problems and poplar stands in a similar soil condition.
Keywords: farming, poplar, crop, sustainability and policy.

1 Introduction

Until the 1980's Polish agricultural production was controlled by the state, whose aim was to produce maximum crops, the results of which strongly impact on the environment, compromised natural resources and the functions of the ecosystem on arable land. Poland's past agriculture intensity reduced soil structure [1] reaped the landscape of vital nutritional elements. Natural habitats, hedgerows, the majority of wetlands and small surface water basins have all but vanished [2], those which remain are (predominantly) highly polluted due to neighboring agro-ecosystems. The 1990s saw the external conditions for farming totally change. Production met the limited market, resulting in decreased prices for primary agricultural products; forcing farms to begin careful management of natural resources, and an initially expensive investment into farming methods, to


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increase productivity. Land, which is more productive, is pushed to excessively productive, whilst less productive land has been abandoned. The government is proposing to re-forest, the so far, 2 million ha of abandoned arable land. For national and international interests the reforestoration is a positive action, however, the tree type requires careful consideration to achieve maximum economic benefits for farmers of this unproductive arable land. Poplar has this potential and timber as an initial crop. It grows fast, and reaches maturity within 25 years. Poplar requirements would combine not available for traditional crop resources [3]. Timber and biomass can revive local economy on the basis of soil productivity. Considering continuity of farm business the surplus of land and other environmental and social resources ought to be engaged in agricultural activity giving not only direct income but also combining into a process of attaining sustainability [4]. Thus, poplar has potential as an extensive crop. The aim of this work is to establish the total expected value from poplar cultivation on a traditional farm in view of a policy driver for long-term sustainability.

2 Sustainability and agriculture

The farm manages ecosystem products and services. Basic human needs that are expected to be provided by the farm are foodstuffs. However, economic viability requires farmers to attentively manage ecosystems and social services provided by the farm. Economic viability means reduction in manpower and implementation of agricultural machinery, but it also means diversification and looking for new markets. Biomass and timber are becoming important crops. Presence of poplars can improve landscape for adaptation and inclusion of land for leisure pursuits. Farmers should engage all resources proportional to the markets, and create new jobs, though economic gain must be balanced with natural processes of a cyclic renewal of resources, which dominate the location. The position of farmers within local community means that they are responsible for the state of resources [5] and the environment over a larger area than just the farm, as farming processes interact with ecosystems [6]. Therefore, sustainable management methods must respect natural resources, while retaining land productivity. By using renewable resources produced under proposed poplar plantation systems, such as biomass, farmers reduce productivity costs and enhance efficiency. Long term changes in agricultural methods require governmental and also farm policies to transform them into operational plans.

3 Methodology

Knowledge based decisions on farm tends to be sustainable and flexible, fully combining resources and farm productivity with respect for ecosystems. When considering the farm as a socio-economic unit, its state is important. An analysis requires a collection of several data sets i.e. economic, socio-economic, and ecological. This will produce a basis for establishing gaps between the actual and sustainable farm status, highlighting obstacles preventing actualization of sustainable methods. Problems encountered by farms in Polish lowlands were

used for this paper. The data were collected qualitatively over a 10-year period by the authors. Each problem the study raised is shown in fig. 1.

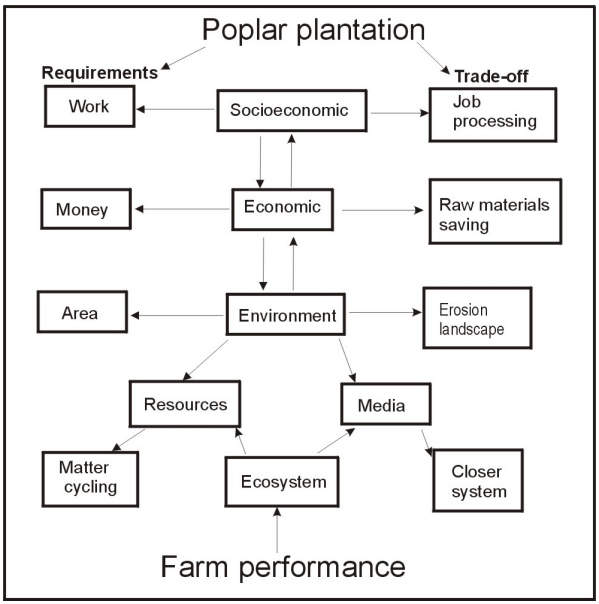

Figure 1: Conceptual diagram presenting the approach to farm analysis.

The diagram (fig.1) enables farm needs to be quantified, and the potential contribution to answer specific farm needs to before filled. Hydrological processes and interaction between soil and trees productivity in time, the retention of biodiversity and active ecosystems need to be considered when establishing the cost both economically and in a sustainable way. The case studies analyzed have enabled quantification of these problems, and the cost of traditional farming methods vs. poplar plantations. The results of the farming combining tradition and poplar crops will be discussed. The data are transformed into economic–efficiency of input, socio-economic-employment, and ecological-N circulation categories.

4 Site locations

All the farms are situated in postglacial terrain with differing relief within a moraine complex and a river valley bottom on the moraine plateau, in a depressing part of the ground within moraine, on the edge of a moraine and a valley as well as in the river valley. All farms need reduced overheads but increased efficient production by utilizing farmed derived biomass, to increase employment opportunities for families and the local community. Farm 5 is located in fragile areas; where surface erosion and loss of organic matter impair

production predominantly. Farms 1 and 3 situated in the river valley are affected during periods of flood. Intense cattle farming in farm 2 and 4, within the river catchments caused nitrogen contamination. The characteristics of each farm are presented in table 2.

Table 1: Functional characteristics of farms.

Specifications		Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
farm areas (ha)		49,75	18,24	70,12	24,88	42,00
in that: forest		0,00	0,00	0,00	0,00	5,00
meadows and pasture		28,06	0,00	32,12	10,28	4,00
set aside		2,94	0,61	0,00	1,10	0,00
arable fields		18,75	17,63	38,00	13,00	32,50
Main crops		Fb, M, B, O, W, T, P	T, P, B, M, Z, B	Sb, P, J, Po	T, B, P, Z, M	R, Po, Mz, Z, Bp
Livestock	Dc	25	0	6	14	4
	C	14	4	0	0	0
	Bc	4	4	0	14	10
	P	5	80	0	100	150
soil bonitation class		Al IV-VI, P IV-VI,	Al IV-VI M IV	Al II- IV M V-VI	Al III-IV, M V, VI	Al IV-VI P
N - mineral fertilizers	a	16,28	49,12	130,49	73,83	95,34
	b	43,20	50,82	240,79	138,46	107,08
N total input yield contents	b	14,46	80,16	52,92	48,76	87,49
Energy input: (GJ/ha/year)		18,89	35,78	33,94	30,3	28,46
in that: renewal		8,38	13,3	8,99	9,39	10,75
Efficiency: Money (PZL/PZL)		1,41	3,54	2,56	5,79	1,95

cropping
W – wheat
T – triticale
B – barley
P – potatoes
Fb – fodder beet
O – oats
R – rye
M – maize

livestock
P – pigs
Dc – dairy cow
Bc – beef cattle
Sc – slaughter cattle
C – calves
P – pigs

Al – arable lands
M – meadows
P – pasture
bonitation class I –VI
a estimate on farm areas
b estimate on crop

Poplar plantations situated on land exhibiting similar characteristics to that of the five farms of the study were analyzed. These comparative sites consisted of 21 poplar plantations on medium to poor quality of soil. The plantations were

established by state forest services on abandoned arable land and meadow (tab. 2). Research into poplar sites was conducted under project PAMUCEAF (FAIR6-CT98 4193).

Table 2: Poplar stands characteristics.

Characteristics	**Description**	**Comments**	**Comparing with arable land**
Suitable site, mineral soil, above 7% average clay content coarse-textured	Underlying coarse-textured subsoils	Possible to form poplar plantations	Low agriculture value
Very suitable Medium-texture	Underlying medium-textured subsoils	Deep subsoil Ground water supply	Also good for traditional crop Not access to ground water
Changes in soil N C	22,14 g/kg 1,82 g/kg	Litter layer is forming,	Two times higher comparing with arable land
Bulk density soil subsoil	1,6 mg/m^3 1,4 mg/m^3	Soil is loosened by roots and macrofauna	Lower then arable soils lower compaction
AWC (available water capacity)	O,06 m^3/m^3	Lower bulk density and larger organic matter retention	Slightly higher then arable soils approximately 0,01-0,02 m3/m4
Contents in soil P K	0,03 g/kg 0,1 g/kg	Soil is clean up Soil matrix contents	In poplar stand three times less The same
Production per year/ha	10-20 m^3	Depend on soil, available water	Similar productivity
N immobile per year	To 200-300 kg	Soil development, biomass enlarging	Accumulation and storing

5 Farmer's needs vs. poplar contributions

Ecosystems confine the threshold of farm productivity within a sustainable system. This needs to be considered when discussing a farming decision for an economic output. This is represented by a group of variables: the state of the farm, farmer's requirements, socio-economic and environmental factors.

Poplar plantations are characterized by two main factors: natural species composition and long duration without human intervention allowing ecosystem development. From tables 2 and 3 it can be seen that poplar planted farms have more positive net gains [7] when compared to similar arable lands. The ability to store nutritional substances and water was higher due to soil developing an accumulation of organic matter and soil loosening volume. The poplars enabled soil to renew its profiles by accumulation and assimilation properties, and also yielding timber and biomass, all positive outcomes of the poplar system (tab.3).

6 Results and discussion

6.1 Quantifying problems on the investigated farm

On each farm one of the key problems was erosion and surplus of resources. They were estimated quantitatively as losses and resources not fully engaged in production. Other categories assessed were: reduction of annual income, decrease in soil productivity (as natural capital), and an ability to cover discounted rates of machinery and equipment. Some factors were considered external factors; they included the effects on the local community and the environment. Surplus nitrogen combined with eroded material deposited in the valley bottom causes pollution and trophication. It can limit farm environment and indirectly local development. The loss of nitrogen, due to geographic location of the farm can be up to 200 kg N per ha/year (farm 5). All farms within the study do not create adequate conditions for crops, hence they reduce yield by approximately 40%. Farm 1 has very extensive production. Farm 3 with meadow situated in a high-risk flood zone causes the farmer to limit productivity (see table 1).

Table 3: Potential contribute of poplar to farm sustainability.

Problem/farmer needs	**Criteria**	**Expectations from new crops**
Decreasing loss	Better efficiency of input Fertility conservation Decreasing leaching of biogens Loss of productivity caused by erosion	Fixed plant cover on fragile land Extensive crop Mixed crop of different requirements
Application for free resources	Biomass Fragile land application	Biomass from extensive long term crop
	Assimilation of N overdose	Assimilation of organic fertilizers
Forming new resources/ Prospect for future	Application for surplus of human and man-made resources	New products/resources carpentry, tourism, leisure
Requirements Poplar stands	Better efficiency of applied resources	Input decreasing Differentiation of activity Improving landscape
	Cheaper input Enhancing income Social acceptation	Crop for abandoned land Replace present crop Silvopasture system
	Capital Labor	

Resources, which are not applied, reduce total farm productivity by 40-60%. One of these is a sub-terrestrial hydrological system, which runs water from the moraine to the valley floor, below the level of accessibility for traditional crop roots. For all farms mechanical and human resources need to be applied more effectively. The two farms (2 and 4), which conduct a secondary productivity results in excess nitrogen being introduced into the valley catchments, externalize effect of farm management.

Table 4: Losses in natural capital and not applied resources in investigated farms.

factors	**criteria**	**characteristics**	**farm**				
			1	**2**	**3**	**4**	**5**
		Soil	3	2	3	1	3
Losses	erosion	Input		2		2	2
	input	Water	3		3	1	1
		Yield	3		2	1	1
	insensitivity	Landscape	1	3		2	1
	Biogens	Surplus of N		3		3	3
Resources	Productivity	Meadows	3		3		1
not	Land	Field	3		3	2	1
applicable	Labor	Human resources	2		3	2	2
	Man-made	Machinery	3	1	3	1	2
	capital						

1 little 2 medium 3 substantial.

Table 5: Capacity of poplar to solve farm problems.

Process	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Apply all forms land	3	1	3	1	2
Low input	3	2	2	2	3
Flexibility	3	1	3	1	2
Development	3	1	3	1	3
Complement production	3		3		2
Biomass	2	3	2	2	2
Secondary production		2	2	1	3
Raw materials/workshops	3	1	3	1	2
Leaching and erosion	1	3	1	3	2
Assimilation	2	1	2	1	3
Extensive permanent crop	3	1	3	1	2
Landscape diversifying	1	3	2	3	2
Naturalness	1	2	2	1	1

Effect vs. problem 1 -3 little, medium, substantial.

6.2 Expected poplar contribution to farms

Farmers cannot afford to allow for further decrease in ecological processes and ecological efficiency. However, the farmer requires mutual gain from protecting these ecological systems, by means of free natural resources to improve production. The solution for many of these environmental and ecological problems is deep-rooted plant cover, which would stop and assimilate nutritional substances. Poplar plantations with solve main problems so far raised but in doing it with different efficiencies. Poplar crops yield raw material, which has a possibility to be processed on the farm; trees as an extensive crop improve soil development by creating better storage capacities for nitrogen and water. Poplars causing soil to become looser, allowing it to be used as strips among fields or part of crop rotation. It has been suggested compaction by heavy machinery causes a dead pan that vanished under poplars. In soil under poplar, phosphorus (P) quantities fall, likely to be caused by P's immobility and assimilation into biomass. Farms proposing such a dynamic system need to consider markets, the environment, and ecosystem processes [8]. Management of these systems and socio-economic systems require specific knowledge and skills to maximize potential outputs. The movement and processing of lumber requires more equipment, machinery, and man-power, a consideration within cost effectiveness of poplar plantations, though the reduction in farm overheads by the use of biomass, may go someway to meeting these costs. Poplar plantations are planned for each farm not in view of above requirements but only due to the farm size, the problem experienced by the farm, both economically and soil degradation, and the proportion of resources free to be engaged within the project. In some cases a part of traditional cropping would be converted into poplars, giving benefits of increased income or meeting local community, or national legislation. Knowing what poplar stand would change in it were estimated proposal in term of stand characteristics considering free resources on farm. In relation to the main problem on particular farm and free resources they dispose, poplar stands differ substantially. Thus contribution to solve problems ranges between 20-80%. The biggest potential contribution of poplar is on farm 2 and 5 no least in farm 2 and 4. That's mean that consequences to farmer needs differ between farms.

7 Conclusion

Comparison between the factors that arise from transformed external conditions for food production and the state of farms enabled to establish threats and gaps in the state that prevents adaptation process. Results of the investigations proved that poplar plantation would positively impact the state and money flow on farms if only the whole farm is designed according to natural processes as surface, interflow and base flow as well nutrients of water flow as well by fitting poplar stands to overall money flow in farm. Farms situated in postglacial landscape in Poland would use poplar as a crop to facilitate achieve the balance their performance with nature and external conditioning for farming. In dependence of

main problem and quantity of free resources on farm, poplar stand would contribute less or more to development of farm business as well as internalization of matter turnover to satisfactory degree.

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