Crop productivity of Central European Permaculture is within the range of organic and conventional agriculture.

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L14. For me, it is confusing to read permaculture sites that work according to organic guidelines, as permaculture is much more complex than organic farming. Can you add here some basic principles of permaculture or guide readers not familiarized with permaculture in which sense you state that these sites work following organic guidelines, please?

1 Abstract

Permaculture is a promising framework to design and manage sustainable food production systems. However, there is still a lack of scientific evidence especially on the crop productivity of permaculture systems. In this first study on permaculture yield, we collected yield data of eleven permaculture sites, that work according to organic guidelines, in Germany and surrounding countries. We used the Land Equivalent Ratio (LER) as index to compare mixed cropping systems of permaculture sites with average monoculture yield data of total and organic German agriculture. An LER of 1 indicates equal yields of the compared polyculture and monoculture. Mean permaculture LER as compared to total German agriculture was 0.80 ± 0.27 and 1.44 ± 0.52 as compared to German organic agriculture, both with no significant difference to 1. Our results imply, that yields of permaculture sites are comparable to predominant industrial agriculture. Provided that future studies will support our findings, permaculture could combine soil, biodiversity and climate protection with agricultural productivity. Most importantly, the variables that determine the difference in crop productivity amoung permaculture sites need to be identified and evaluated.

L18. What does total german agriculture mean? Please, rephrase and clarify this expression.

L23. “among”

Keywords: agroecology, permaculture, regenerative agriculture, sustainable agriculture, productivity, crop yield, land equivalent ratio

Abstrac, L21. This part of your sentence sounds weird as you do not provided any discussion about why you obtained such results, not even a possible explanation of your expectations in the introduction section. Why permaculture is a promising framework? Why we need to measure crop productivity in a system that is much more than measuring productivity? Is this the argument that we need in order to promote permaculture? If you do not explicitly associate your results to any permaculture principle, why should we expect that future studies will support your results? I suggest you introduce a brief discussion and then the idea that you will expect similar results in future studies.

2 Introduction

Modern industrial agriculture, characterized by high chemical inputs, monocropping and intense soil cultivation, has led to environmental degradations such as soil erosion and loss of biodiversity (Millennium Ecosystem Assessment 2005; Foley et al. 2005; Campbell et al. 2017). In response to these challenges, alternative farming approaches, that prioritize ecological sustainability and regenerative practices are gaining

L29-31. Maybe you can add information about crop productivity associated to industrial agriculture, say something about yield decreases in the last decades? Not sure you have specific information for Germany but this is a point that it is being discussed by many agroecologists and that it is related with your study.

increased attention, such as agroecology (Barrios et al. 2020), regenerative agriculture (Schreefel et al. 2020) or diversified farming systems (Kremen et al. 2012). A promising framework for the design and management of those food production systems is permaculture (Mollison 1992; Ferguson and Lovell 2014; Krebs and Bach 2018).

Permaculture is an agroecological design system that draws inspiration from natural ecosystems and traditional and indigenous farming practices (Mollison 1992). It emphasizes the integration of a diversity of crops, with a focus on perennial and woody crops, and livestock to create self-sufficient and resilient agricultural systems (Morel et al. 2019). By mimicking the patterns and relationships found in natural ecosystems, permaculture seeks to optimize resaource use, promote biodiversity and enhance ecosystem health (Ferguson and Lovell 2014). Examples for these patterns are diverse polycultures, permanent soil cover, a focus on woody crops, the integration of crops and livestock as well as management of grazing animals in densely packed herds (Krebs and Bach 2018). Amongst others, permaculture principles emphasize practices like polycultures, agroforestry systems, crop-livestock integration, facilitation of semi-natural habitats to enhance pest control and pollination, as well as soil conservation techniques such as mulching, composting and no-till cultivation (Reiff et al. 2024).

resource

Implementing these principles, permaculture sites showed strong improvements in soil quality, soil carbon storage and biodiversity compared to predominant agriculture in Central Europe (Reiff et al. 2024). In addition, permaculture strives for a holistic approach that not only focuses on agricultural production but also considers social and economic aspects that aim for sustainable livelihoods and community resilience (Holmgren 2002). Although there is some evidence that permaculture can be an ecologically sustainable farming practice, there is a lack of scientific research on its crop productivity (Morel et al. 2019). The few existing studies have focused only on economic performance (Morel et al. 2015), income diversity (Ferguson and Lovell 2017) or qualitative interviews of farmers (Conrad 2014). Therefore, this study aims to evaluate the land productivity of permaculture sites by comparing their yields to those of predominant modern agriculture in Central Europe. We used the Land Equivalent Ratio (LER) as an established tool to evaluate the productivity of mixed crop permaculture sites (Martin-Guay et al. 2018). The LER is widely used for situations with intercrops of no more than two species while evidence from combinations of three crops is scarce, with one study investigating a combination of seven crop species (Deb 2021; Deb et al. 2022). In this case, it was not feasible to conduct a single-crop experiment for every crop variety at each permaculture site. Mean values from larger samples were used to determine sole crop yields in some cases (Böhm et al. 2020), or they were estimated from the intercropping experiment itself (Seserman et al. 2018). The approach of using maximum or average sole crop yields was also described by (Mead and Willey 1980). Therefore, we used national average yield data as sole crop yield values in this study. By quantifying and comparing the yields of permaculture sites with predominant industrial agricultural systems, we provide insights into the potential benefits and limitations of adopting this approach.

L 48-52. I suggest this paragraphs should be incorporated to the next one.

Why land productivity in a system that has another conception of "land", "economy", etc.? I feel that you do not provide a good justification of why measuring yield, something that in isolation is completely functional to industrial agriculture [you will need a given yield per land because of the economic conception of industrial agriculture]

Maybe you should consider a last paragraph from L56 Therefore, this study...

Mead and Willey (1980)

L56-68. Something important to be said in your study is the fact that as industrial agriculture produce commodities (do not think about crops as real food), there is no need to cultivate all lands that are already been cultivated). This is important to discuss the way we need to measure permaculture yields... I am not saying that we do not need to do this, but for a very different reason associated to other ways of thinking about economy and life. Is this vein, I suggest you introduce better the arguments about why measuring yield in permaculture systems [as mentioned above].

3 Materials and methods

3.1 Study sites

This study evaluates yield data from eleven commercial permaculture sites in Germany (Rhineland-Palatinate, Bavaria, North Rhine-Westphalia and Lower Saxony), Switzerland, and Luxembourg, which either constitute a farm or are part of a farm. (Tab. 1). Three criteria were used for site selection. First, permaculture sites had to be designed and managed with permaculture, according to the farmer. Second, we only investigated commercial permaculture sites to focus on food production systems and to exclude permaculture sites established mainly for other purposes like subsistence or education. Third, at least two different types of land use (e.g. grazing and fruit trees) had to be integrated at the agroecological production. We have considered all farms in Germany and the surrounding regions, that met the specified criteria and were willing and able to provide their yield data. This data represents the crop yields sold by the farms and was collected by the farms themselves. Yield datasets covered one year per farm between 2019 and 2022 and only crop yields from permaculture areas allocated mainly to crop production. Livestock yields and grazing areas were excluded, as the majority of livestock production in Central Europe is based on imported forage and therefore not directly comparable in terms of land requirements. Farms were rather young with a mean age of 6 years at investigation. Therefore areas dominated by newly planted berry bushes or fruit trees, not having reached full yield potential, were excluded from the evaluation. All farms followed the principles of organic agriculture, although not all were certified. Permaculture sites 2, 3, 6 and 8 were part of a separate study on soil quality, carbon storage and biodiversity of permaculture (Reiff et al. 2024). These sites share identical identifiers in both studies.

L76-77. I do not understand this sentence. What do you mean with "had to be integrated at the agroecological production?

assigned?

Which ones? Maybe you can add a reference?

I suggest you provide a map to see the geographic distribution of sites

3.2 Reference data

To compare permaculture yields with predominant industrial agriculture, data by the Federal Statistical Office of Germany for German agriculture of respective years was used for vegetables and strawberries (Federal Statistical Office 2023a), potatoes (Federal Statistical Office 2023b), tree fruit (Federal Statistical Office 2023c), and other soft fruit (Federal Statistical Office 2023d). These surveys are representative of Germany. Data was collected from 5,100 farms in 2019 and 2020, and from 4,500 farms in 2021 and 2022 (Federal Statistical Office Germany, 2024; personal communication). Throughout Germany, most arable land parcels are used for single crop cultivation (Blickensdörfer et al. 2022). These datasets included mean crop yield data of total German agriculture (Y_{tot_year}) and organic German agriculture (Y_{org_year}). For vegetable or fruit varieties that were not covered by these collections, mean values of respective vegetable group (such as legumes) or of all tree or soft fruit was were used for comparison (e.g. $\overline{Y}_{tot\_2022}$(cabbage vegetables) for Y_{site1_2022}(pak choi)). For organic production, vegetable yield values were only given for vegetable groups of root and tuber, fruit, leaf and stalk, cabbage and other vegetables as well as legumes (e.g. Y_{org_2022}(legumes)). Thus, a ratio of organic to total agriculture was calculated for each group and year (e.g.

L93-94. This means that you compared data from different countries with data coming from Germany? How much representative for other countries can be German results?

About the section "Reference data". Reference data is constructed with data on 5,100 and 4,500? This makes your comparison problematic, because of two main reasons: (1) variance will certainly be higher for industrial agriculture just because you use an enormous dataset compared to that associated with permaculture, which may introduce a bias in your results; (2) industrial agriculture certainly covers different soils, that may lead to very different yields even under monoculture, which may also include noise in your results. I suggest you keep sites geographically comparable with your permaculture sites, with similar land size and soil [in terms of the "original" soil structure], and then performe comparisons. Alternatively, you should take a group of "comparable" farms and perform bootstraps analyses.

R_{2022}(legumes)=Y_{org_2022}(legumes)/Y_{tot_2022}(legumes)). To estimate the organic yield data of specific crop varieties, the total crop yield data of those varieties was multiplied by the respective total to organic vegetable group ratio (e.g. Y_{org_2022}(sugar pea)=Y_{tot_2022}(sugar pea)*R_{2022}(legumes)). To estimate organic potato yield, total yield was multiplied by organic to total root and tuber vegetable ratio (Y_{org_2022}(potato)=Y_{tot_2022}(potato)*R_{2022}(root and tuber vegetables)). For tree crops organic yield data was only available for 2022, so an organic to total ratio was calculated from this data (e.g. R_{2022}(apple)=Y_{org_2022}(apple)/Y_{tot_2022}(apple)) and applied to data of the other years (e.g. Y_{org_2019}(apple)=Y_{tot_2019}(apple)*R_{2022}(apple). Nut crops were only grown on one permaculture site and were a relatively small proportion of total production. (Tab. 2). Nut yield data of German agriculture was not available, therefore general literature values were used for comparison of walnut (Cerović et al. 2010) and hazelnut (Erdogan 2018) yields. Tree crop organic to total ratio was applied to estimate organic nut yield values (e.g. Y_{org_2022}(hazelnut)=$Y_{erdogan\_2018}$(hazelnut)*R_{2022}(tree crops).

Table 1: Investigated Farms with permaculture. Only crop types written in italic were investigated in this study. The remaining crop types were excluded from the investigation as they were either newly planted woody crops, from areas primarily designated for livestock production, or from non-permaculture areas.

Site	Country	Establish-ment	Survey	Farm area [ha]	Investigated area [ha]	Farm plant production	Farm livestock
1	Switzerland	2011	2021	2,5	0,02	*vegetables, soft fruit,* tree crops, grassland	
2	Germany	2009	2019	10	0,44	*vegetables, soft fruit, tree crops,* grassland, grains	chicken, pigs, geese
3	Germany	2009	2019	3,6	0,66	*vegetables, soft fruit, tree crops,* grains	chicken
4	Switzerland	2020	2021	5	0,06	*vegetables,* soft fruit, tree crops, grassland	chicken, sheep
5	Germany	2019	2021	1,9	0,22	*vegetables*, soft fruit, tree crops	runner ducks, chicken
6	Luxembourg	2014	2020	1,5	1,01	*vegetables, soft fruit, tree crops*	runner ducks
7	Germany	2018	2021	3,5	1,60	*vegetables,* tree crops	
8	Germany	2013	2022	1,1	1,06	*vegetables,* soft fruit, tree crops	
9	Germany	2022	2022	0,4	0,06	*vegetables, soft fruit,* tree crops, grassland	sheep
10	Switzerland	2015	2021	3	0,32	*vegetables, soft fruit, tree crops*	
11	Germany	2017	2022	2,4	0,15	*vegetables,* soft fruit, tree crops, grassland	chicken, pigs, sheep

I am not so familiarized with permaculture, I have been working with agroecology most of the time. In general, farms transitioning to agroecology start to see results in soils after three years and in yields after five years... In this sense, how informative are these three farms that I highlighted? Maybe you can include information on land use before starting permaculture in those farms?

3.3 Land Equivalent Ratio

In all cases, permaculture sites consisted of mixed cultures of different vegetable varieties and often additional fruit trees and berry bushes. Added integration of livestock was common, but resulting extra animal yields are not include-able in this study. The land equivalent ratio (LER) is used as an index to

check, please

assess the relative productivity of these mixed crop systems compared to the mean sole crop productivity of total and organic German agriculture in the respective years (Mead and Willey 1980; Risch and Hansen 1982; Bomford 2009; Reynafarje et al. 2016; Paut 2018). The LER for a specific permaculture site *site* as compared to one of the management categories *man* (total or organic German agriculture) was calculated as follows

L132-133. I do not see clearly what is the reason of these comparison using so many farms across Germany as you have 11 sites with clearly defined soil, climatic and ecological conditions (among others) that will limit their production. I am ok with your formula but not with the reference group, as it may confound so many factors that looking at differences among industrial agriculture and permaculture will result non-informative for me, even if I found very intersting to know permaculture yield. Moreover, I suggest you investigate also yield interannual variation, as one of the reasons to adopt other agricultures is related with yield stabilization across years.

$$LER_{man,site} = \sum_{i=1}^{m} \frac{Y_{site}(i)}{Y_{man,year}(i)}$$

where m is the number of different crops yielded at the permaculture site, $Y_{man,year}(i)$ is the monocultural yield of the i^{th} crop of respective management and year and $Y_{site}(i)$ is the yield of the i^{th} crop under intercropping of the permaculture site. Two LER values were calculated for each permaculture site, one compared to total German agriculture and one compared to German organic agriculture. An LER of 1 indicates equal productivity of the permaculture mixed system and statistical data sole crops. Example calculation for yield data of permaculture site X from 2019 in comparison with total German agriculture and of just two crop varieties:

I do not understand what is the meaning of comparing with "total" agriculture, instead with organic and industrial/conventional agriculture

$$LER_{tot,siteX} = \frac{Y_{siteX}(potatoes)}{Y_{tot,2019}(potatoes)} + \frac{Y_{siteX}(bush\,bean)}{Y_{tot,2019}(bush\,bean)} = \frac{25\,t/ha}{39\,t/ha} + \frac{5\,t/ha}{10\,t/ha} = 0.64 + 0.5 = 1.14$$

3.4 Statistics

Statistical analysis was carried out using R (R 4.2.1, R Development Core Team 2022). Both samples of LER values (compared to total or organic German agriculture) were checked for normal distribution visually using the function *qqplot()* as well as mathematically using a Shapiro-Wilk-Test with the function *shapiro.test()*. A one sample t-Test was used to test both groups of LER values against the specified value of 1 using the function *t.test()*.

L145. This is surprising as you do not develop these ideas in the introduction section. Why introducing predictor variables here? You need to contextualize your statistical decisions and they need to be in line with the questions and aims you present in the introduction section

Two linear models were calculated using the function *lm()* with total LER or organic LER values as response variables and age, investigated area and presence of livestock as predictor variables. Automated model selection was performed using the *dredge()* function. Model diagnostics to check for deviations from the model assumptions (normal distribution, homogeneity of variance, etc.) were performed visually using the *plot()* function on the linear model outputs. The significance of the predictor variables was evaluated with a Type II F-test using the Anova function of the 'car' package (Fox et al. 2023) on the full model, since no model with significant predictors was found (Table 2).

Values in the text are given as mean plus minus 0.95 confidence interval.

4 Results

A total of 79 crop varieties were found on the permaculture plots to calculate LER values. The permaculture sites produced a total of of 93.6 % vegetables, 5.8% tree crops and 0.5% soft fruit.

On average, the crop yield of permaculture sites was 21,8 ± 7,3 t ha^{-1}. Table 3 displays the total crop yield and proportions of different crop types for each permaculture site. Mean permaculture site LER as compared to total German agriculture was 0.80 ± 0.27 and 1.44 ± 0.52 as compared to organic German agriculture (Fig. 1, Tab. 2+3). The permaculture LER of 0.80 suggests that permaculture requires 20% more land to achieve the same yield as total German agriculture, resulting in a non-significant 20% lower permaculture productivity. Consequently these results suggest a by trend 44% higher permaculture productivity compared to organic German agriculture.

L159-162. These sentences should be moved to the discussion section. Moreover, I think you should discuss about permaculture needing to reach such similar yield. This is because industrial agriculture thinks about crops as commodities, not as food or people food requirements. In fact, the diversity of crops provided by permaculture may make it a more productive agriculture in terms of quantity and quality of the food produced. I understand your point about comparing yield among different agricultures, but you should keep in mind the main critics to industrial agriculture when discussing your results.

LER values as compared to total German agriculture and to German organic agriculture both were not significantly dependent on any of the tested predictor variables: farm age, investigated area and presence of livestock (Tab. 2).

L163. These results need to be linked to the whole proposal of the article. I understand that you include them because they can affect crop yield? See my previous comment on the section "statistics"

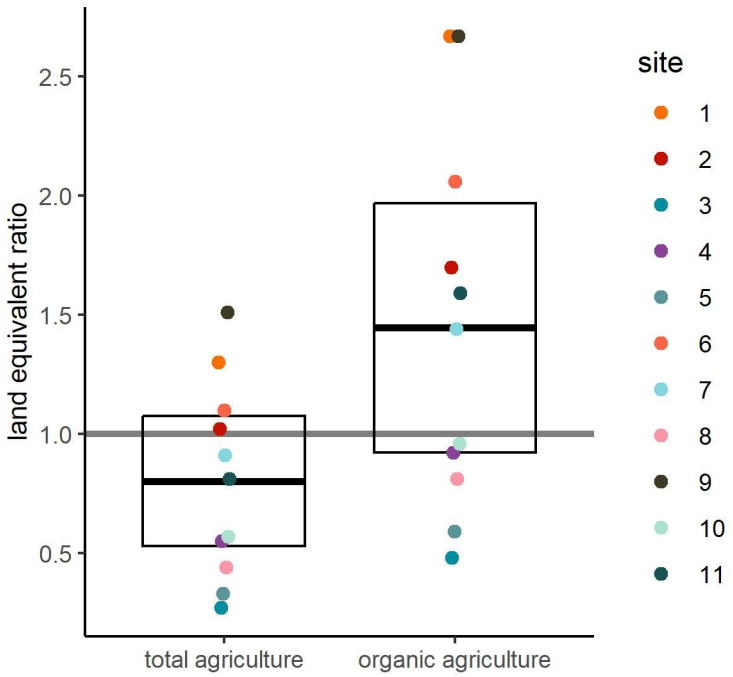

Figure 1: Land equivalent ratios (LER) of permaculture. LER's of eleven permaculture sites as compared to total (p=0.137, t=-1.62, df=10) and organic (p=0.087, t=1.98, df=10) German agriculture. Bars with error bars indicate mean and 95% confidence interval, coloured dots indicate individual data points and horizontal line indicates equal land requirement of permaculture and reference.

5 Discussion

Both mean LER values were not significantly different from 1, indicating no significant difference in permaculture productivity compared to average German agriculture. This indicates that yields of permaculture sites are comparable to predominant industrial agriculture. The by trend higher productivity compared to German organic agriculture even suggests a potential of permaculture to bridge the productivity gap between organic and conventional agriculture. However, LER values varied strongly between individual

178 permaculture sites. A recent meta study found a mean LER of 1.36 ± 0.04 with a similar range from 0.5 to
179 2.6 for intercropping of vegetables and/or fruit trees (Paut, 2018). This value corresponds to the permaculture
180 LER of this study as compared to German organic agriculture in general, as the permaculture farms were
181 operated according to organic farming guidelines. As the mean permaculture LER is substantially higher
182 with 1.44 ± 0.52, its difference from 1 might therefore be largely explained by the use of intercropping.

183 It is likely, that permaculture yields are even higher than reported in this study. At some permaculture sites,
184 yields of soft fruits, tree fruits and nuts from areas with mainly vegetable production were not recorded by
185 the farmers. Additionally, feed provisioning from investigated areas for livestock integrated in crop
186 production could not be taken into account in this study. Such provision constitutes an additional yield
187 produced within the same area, reducing the need for external feeds. This includes runner ducks or chicken
188 for permanent or temporal pest control on vegetable areas; sheep, geese or chicken grazing below woody
189 crops or pigs fed with crops not suitable for sale.

190 **Table 2: Statistics.** Results of t-Tests and linear models on the Land-Equivalent-Ratios (LER) of 11 permaculture sites
191 as compared to total German agriculture and to German organic agriculture fitted in R.

Response variable	Test	Explanatory variable	t/F-value	P-value	df
LER (total)	One sample t-Test against 1	NA	-1.62	0.137	10
LER (total)	Linear model	Age	<0.00	0.995	7
LER (total)	Linear model	Investigated area	0.02	0.904	7
LER (total)	Linear model	Presence of livestock	0.24	0.641	7
LER (organic)	One sample t-Test against 1	NA	1.98	0.087	10
LER (organic)	Linear model	Age	0.03	0.864	7
LER (organic)	Linear model	Investigated area	0.13	0.734	7
LER (organic)	Linear model	Presence of livestock	0.18	0.688	7

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193
194 LER values were not significantly dependent on any of the tested predictor variables. Nevertheless, the
195 variability of the permaculture LER values was high. Permaculture is a very context specific design tool,
196 thus every permaculture system is different. A high variance among permaculture sites was also found for
197 increases in soil quality, carbon storage and biodiversity compared to predominant agriculture in Central
198 Europe (Reiff et al., 2024). We assume that variance in permaculture LER's is a result of a combination of
199 different factors such as the degree of complexity, the management intensity, the age of the system as well as
200 the experience of the farmers. The degree of complexity varied among permaculture sites and could be
201 determined by the level of spatial and temporal integration of different land use elements. This can range
202 from the mixed cultivation of vegetables to agroforestry and the integration of different types of livestock. A
203 recent experiment showed, that LER's of mixed culture of seven annual crops varied between 1.18 and 5.67
204 depending on cropping design (Deb, 2021). Also, the level of management intensity differed between
205 permaculture sites, from more extensive systems with a stronger focus on nature conservation and input
206 efficiency to more intensive systems with a higher input of labour and resources. Ultimately, the
207 effectiveness of a permaculture system may hinge on the farmer's experience and competence in handling
208 such a multifaceted system. Hence our results suggest, that well planned and managed permaculture systems

209 are able to be as productive as prevalent industrial and especially organic agriculture. Still, on average
210 permaculture seems to be able to reduce the yield gap of organic agriculture while still working according to
211 its guidelines. A global meta-analysis revealed that, mean organic agriculture yields were 25% lower
212 compared to those of conventional agriculture (Seufert et al., 2012). At the same time, permaculture seems to
213 strongly improve environmental conditions of the agroecosystem in terms of soil quality, carbon storage and
214 biodiversity (Reiff et al., 2024).

215 **Table 3: Crop yield of permaculture sites.** Land-Equivalent-Ratio of eleven permaculture sites in Germany and
216 neighbouring countries as compared to total (LER total) and organic (LER organic) German agriculture. Yield includes
217 crop yield of vegetables, tree crops and soft fruit. The proportions of vegetable groups, soft fruit, tree fruit and tree nut
218 in the total yield of the permaculture site are given as percentage values.

219

site	LER total	LER organic	yield [t/ha]	root/tuber veg. [%]	fruit veg. [%]	cabbage veg. [%]	leaf/stalk veg. [%]	legume [%]	other veg. [%]	soft fruit [%]	tree fruit [%]	tree nut [%]
1	1,30	2,67	20	4	68	1	13	0,5	0,0	13,4	0,0	0,0
2	1,02	1,70	17	30	18	21	26	4,8	0,0	0,0	0,0	0,0
3	0,27	0,48	32	29	33	14	7	2,5	0,0	1,4	11,8	0,3
4	0,55	0,92	7	37	37	6	18	0,5	0,0	2,1	0,0	0,0
5	0,33	0,59	31	21	24	17	20	1,4	0,0	0,1	17,0	0,0
6	1,10	2,06	12	17	39	10	29	4,2	0,1	0,0	0,0	0,0
7	0,91	1,44	7	27	25	3	41	3,9	0,0	0,0	0,0	0,0
8	0,44	0,81	32	37	21	27	15	0,6	0,0	0,0	0,0	0,0
9	1,51	2,67	45	27	41	13	14	4,0	0,0	0,2	0,0	0,0
10	0,57	0,96	11	19	9	17	31	6,0	0,1	6,4	11,4	0,0
11	0,81	1,59	26	13	33	7	44	0,3	2,1	0,0	0,0	0,0

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222 Common permaculture literature suggests to rely on annual crops until woody crops are established and
223 reaching full yield (Shepard, 2013; Perkins, 2016). The high proportion of vegetable yield found on all
224 permaculture sites in this study aligns with their recent establishment (Tab 1, Tab 3). The viability of
225 permaculture sites relying mainly on vegetables could be evidenced in a case study in France. Here, on a
226 permaculture site measuring 1000 m^2 one person produced an income ranging from 900 to 1600 € per month,
227 with a mean workload of 43 hours per week (Morel et al., 2015). In addition, a study in the USA found
228 permaculture farms to fit well within the emerging framework of diversified farming systems, with a high
229 diversity of production and income, including non-production enterprises, to develop and maintain diverse
230 agroecosystems (Ferguson and Lovell, 2017). In Malawi, farmers experienced economic and nutritional
231 benefits from utilizing permaculture through increased, more diverse and more stable yields (Conrad, 2014).
232 This first study on permaculture yields in Central Europe demonstrates that permaculture also has the
233 potential to compete with industrial methods in temperate climates.

6 Conclusion

Our findings suggest that well-planned and managed permaculture systems can obtain productivity levels comparable to industrial agriculture while adhering to guidelines of organic agriculture. This highlights the potential of permaculture to bridge the productivity gap between organic and conventional agriculture, while regenerating agroecosystems. Further promotion and adoption of permaculture principles could enhance sustainable food production and reduce reliance on industrial farming methods.

The limited scope of this study with eleven sites and yield data from only one year needs further and larger studies to confirm our results. In addition, the high variance of LER values among individual permaculture sites indicates the need for more research focused on understanding the factors influencing productivity in permaculture systems. Future studies should investigate larger samples of permaculture systems from different continents and climates, as well as the level of complexity, management intensity, and farmer experience to determine their impact on permaculture yields. Additionally, exploring long-term effects of older permaculture systems, including staple crop (e.g. grains) and livestock yield, and comparing them to conventional agricultural practices would provide valuable and much needed insights.

L244-245. I suggest you add more information about these factors/variables that would be interesting to compare among permacutlural systems, as many readers may not be able to understand what complexity, management intensity or farmer experience will be in permaculture. Maybe you can provide examples for each factor/variable.

7 Acknowledgments

We thank the Heinrich-Böll-Foundation for funding a PhD scholarship supporting this research and all farmers involved for making this study possible.

8 Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

9 Availability of data and material

The datasets generated during and/or analyzed during the current study will be made openly available.

10 Author Contributions

Funding acquisition, methodology development and original draft preparation were done by Julius Reiff. Data acquisition and analysis was done by Julius Reiff and Nicole Antes. Conceptualization was done by Hermann F Jungkunst, Martin H Entling and Julius Reiff. Review and editing was done by all Co-Autors.

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