

**Appendix A Supplementary data**

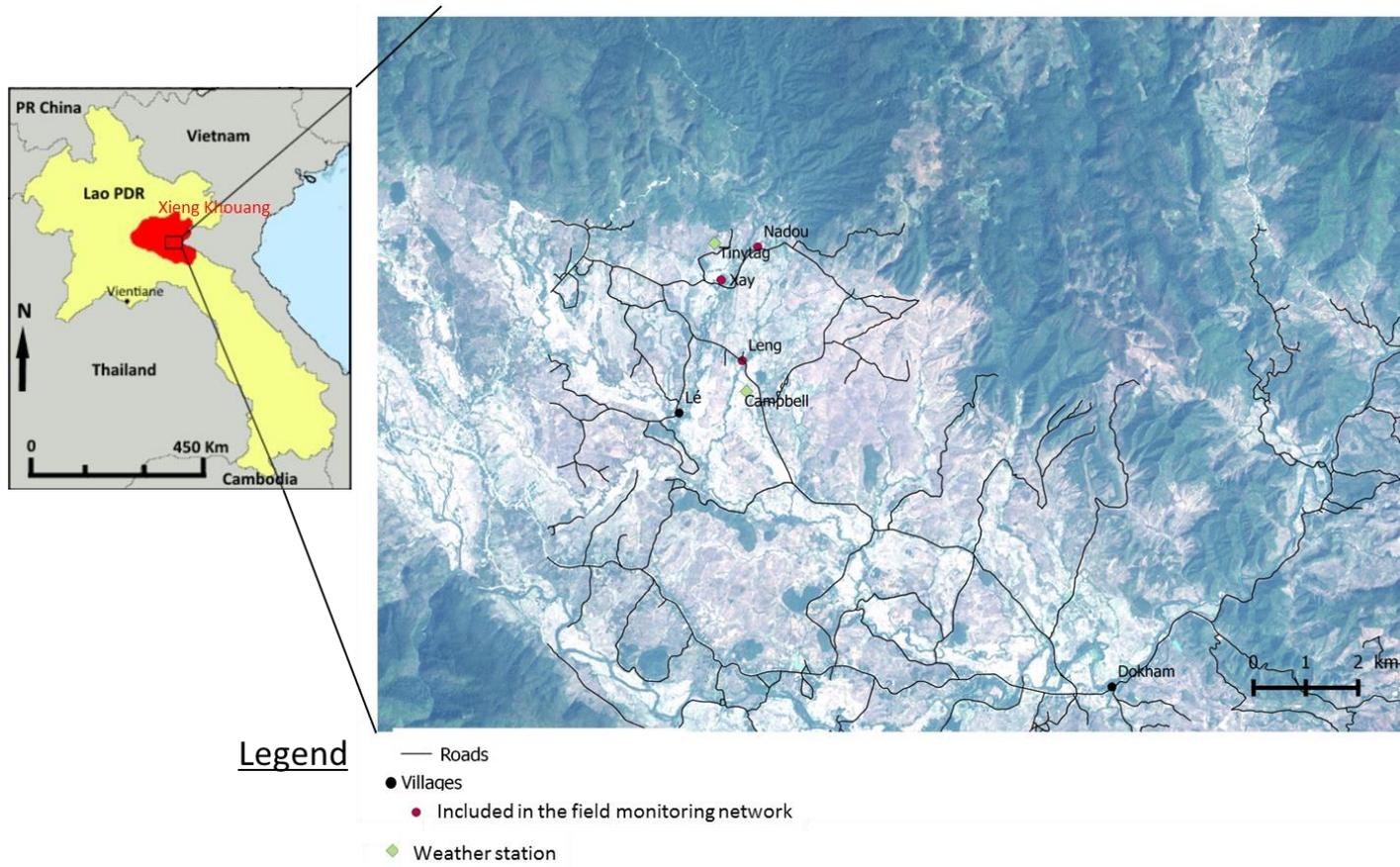


Figure S1: Map of the study region, Kham District in Xieng Khouang province in Lao PDR.

Table S1: Q-sort average values for each statement for the three types of opinions revealed by the Q-methodology.

	Opinions		
	O1	O2	O3
1. Soils fertility has decreased because of ploughing every year	1	0	0
2. If the soil is black, it is a fertile soil and if the soil is red or yellow it is an unfertile soil	4	-2	-3
3. A fertile soil is soft and has a good structure after ploughing	0	5	3
4. No matter the colour and the structure of the soil, a fertile soil is the one with high yield without fertilizer addition	-1	-5	-1
5. Legumes crops can improve soil fertility	5	0	1
6. Maize grows well even if the soil is not fertile, unlike other upland crops	-5	-2	-4
7. Growing maize every year makes soil fertility decline over the years	0	1	0
8. Soils in flat land cleared from very old forest remain fertile even after 15 years of maize cultivation	3	4	4
9. The use of herbicide makes the soil less fertile	0	-2	-4
10. Mineral fertilizer are making the soils stronger	-5	0	-4
11. High yield is not the only criteria to know if the soil is fertile or not	-2	1	3
12. Unfertile maize fields have a lot of weeds	-3	-5	-3
13. If the soil is unfertile I cannot have good yields even if I put fertilizer	-1	-3	2
14. It is important to prevent soil fertility loss even if we have a lower income today by doing so	2	-4	0
15. It is important to prevent soil fertility loss even if we have to work more by doing so	1	-1	4
16. Even if soil fertility has changed it is not a big problem because farmers are wealthier thanks to maize	-3	0	1
17. I want to preserve the fertility of my soil for the future farm of my children	4	1	2
18. Farmers have a duty to conserve soil for the next generation, whatever the impact on today's profits	2	-4	2
19. Maintain soil fertility is not only about immediate yield, it is a long term investment	1	-1	2
20. I prefer to have a high income today because I need money immediately, even if I don't preserve soil fertility	-4	-3	-2
21. Farming practices today will impact the future generations but there is no other alternative	-2	0	4
22. Fertilizer and cow manure are the same for fertility improvement	-3	-2	-5
23. Maintaining soil fertility is not labour intensive	-4	-3	-5
24. It is not worth it to invest time and money in soil fertility	-4	-2	-2
25. The soil is fertile when it gives enough food to the plants to grow without mineral fertilizer addition	5	4	5
26. The soil is unfertile when young maize is yellowish	4	2	3
27. Even if today soil fertility is low, soil has the capacity to be fertile again if we let him rest long enough	1	1	-2
28. Soil is degraded for good, it is not possible to come back to the way it used to be before maize	-3	-3	-1
29. Soil erosion leads to a decline in fertility because the most fertile layer disappears	2	3	5
30. Fallow was used before maize to make the soil rest and soil fertility increase	3	4	3
31. There are green and very beautiful maize in the village, it is the sign that the soils are still fertile in some areas	3	2	0
32. Soils that dry quickly is a sign of low fertility	-2	-1	0

33. When there is enough rain most of the soils of the village still are able to give good yields	1	3	2
34. The soils are addicted to fertilizer and need more of it than in the past	1	2	0
35. If the soil is deep, I know for sure that the soil is fertile	3	1	1
36. There are special species of weeds that are only in unfertile soils and other species of weeds only in fertile soils	0	2	-1
37. Low crop yield in a good climatic year is an indicator of low fertility	2	2	1
38. Fertility degradation is not the principal factor in yield decrease, other more important factors explain low yields	-2	0	1
39. Water stress at the beginning of the cropping season is the main cause of low yield compare to low soil fertility	-1	0	-3
40. Weed invasion is the main cause of low yield compare to low soil fertility	0	1	0
41. Low maize density is the main cause of low yield compared with low soil fertility	-1	-1	-1
42. Soils are more exhausted than before but could give more yield today thanks to mineral fertilizer, good variety and herbicide	-2	-1	-1
43. Some soils were unfertile before maize, other became unfertile due to maize cultivation	-1	-4	-2
44. A fertile soil is a soil where it is easy to obtain a satisfactory plant density at emergence with a seed drill	0	3	-3
45. A fertile soil is a soil where it is easy to obtain a satisfactory plant density at emergence even if rainfall events are scarce	2	3	-2
46. A fertile soil is a soil where it is easy to obtain a good density at emergence despite heavy rainfalls	0	-1	1
47. After ploughing, a fertile soil has clods that easily burst with rainfall	-1	5	-1

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A



B

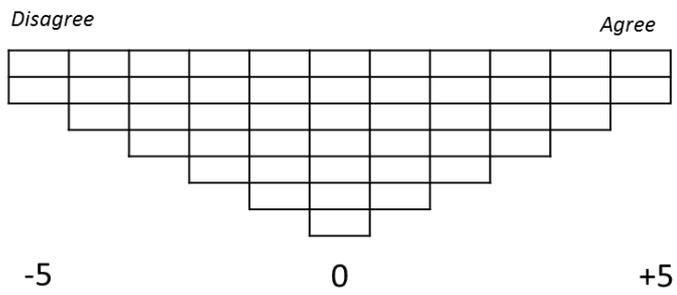


Figure S2: The Q-method with A) farmers reading the statements of Q-method and B) the normal design following which farmers had to place the statements.

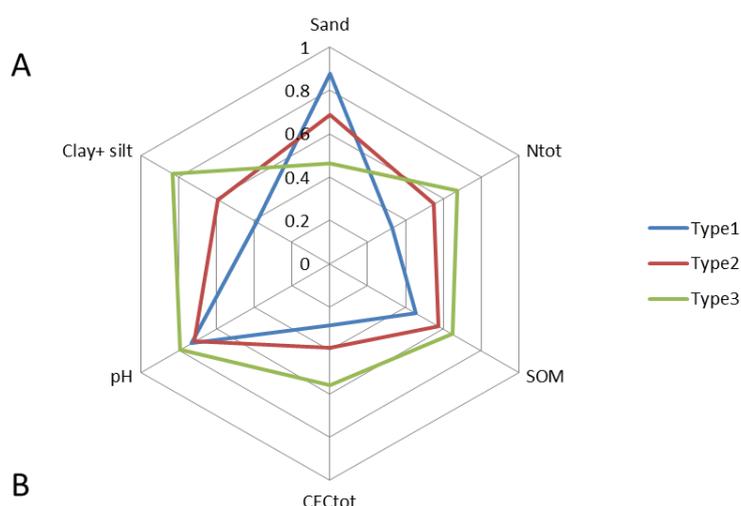
Table S2: List of all the constraints and sustainability issues possibly occurring in maize areas of Kham basin and suspected causes according to the initial knowledge from literature (extended to northern Laos).

Some sources were published after 2016, the year of set up of the field monitoring network but were useful to illustrate the local discourse on constraints and expected causes afterward.

Constraints	Suspected causes	Source
<ul style="list-style-type: none"> <li>Economic performances</li> </ul>		
Low maize yields	Soil fertility decrease	Farmers interviews +literature (Southavilay et al., 2012)
Low prices/unstable markets	?	Farmers interviews
High costs	Fertilizer, herbicide, hybrid seeds	Farmers interviews
<ul style="list-style-type: none"> <li>Agronomic performances (yield)</li> </ul>		
Low nitrogen availability	Low soil fertility due soil nutrient depletion caused by maize mono-cropping  No fertility management	Farmers interviews +literature (Viau et al., 2009)
Weed	Weed resistance to herbicide	Farmers interviews
<ul style="list-style-type: none"> <li>Environmental impacts</li> </ul>		
Erosion, soil degradation	Slopes, bare soils, heavy rains	Literature  (Dupin et al., 2009; Kallio et al., 2019; Valentin et al., 2008)
Herbicide leaching	High amounts of herbicide	Literature  (Bartlett, 2016)
Deforestation	Maize expansion	Literature  (Kallio et al., 2019)
Biodiversity	Landscape segregation/homogenisation due to mono-cropping	(Castella et al., 2013; Viau et al., 2009)
<ul style="list-style-type: none"> <li>Social impacts</li> </ul>		

Farmers Indebtedness, risks	High cash needed for maize cultivation	Literature (Hepp et al., 2019; Viau et al., 2009)
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**Figure S3: Soil diversity on field monitoring network.** On fig S3.A, for each attribute of soil type data are expressed in ratio [mean of attribute for the type]/[maximum value of the attribute on the total sample]



**B**

Soil type	Sand (%)	Ntot (g kg <sup>-1</sup> )	SOM (%)	Total CEC (me/100 g)	pH	Clay + silt (%)
Type 1 15.51% of plots	71.1	0.47	1.7	4.91	5.57	28.91
Type 2 15.51% of plots	55.74	0.791	2.166	6.72	5.45	44.27
Type 3 68.98% of plots	37.59	0.96	2.44	9.7	6.01	62.4

References of supplementary material:

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Kallio, M. H., Hogarth, N. J., Moeliono, M., Brockhaus, M., Cole, R., Waty Bong, I., and Wong, G. Y. (2019). The colour of maize: Visions of green growth and farmers perceptions in northern Laos. *Land Use Policy* **80**, 185-194.

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