2.8 Switzerland

Historical agroforestry experimentation in Europe

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Introduction

After a brief review of the history of European agroforestry, the results of some historical agroforestry experiments are presented and discussed in the context of the SAFE project. This report is preliminary and it is intended to complete this information by further literature search.

The history of European agroforestry

At its beginning, European agriculture was based on shifting cultivation. Tree based agricultural systems are reported from Roman times (Lelle & Gold, 1994) and until about two centuries ago, many European forests were significant sources of food and were grazed with ruminants and pigs (Brownlow, 1992). There actually was no distinct limit between forest and agricultural land and the input of organic matter and energy necessary to keep agriculture sustainable came from forests in the form of fodder, litter and wood (Haber, 1994). As an example, Eckert (1995) estimated that in the Neidlingen valley (Baden-Wurttemberg, Germany) until about 1500, the forest provided three quarters of the nitrogen and 90 % of the phosphorous available for the fertilisation of fields, vineyards and gardens.

In the 18th and 19th century, intercropping on cleared forest land between rows of planted or sown forest trees was common practice in many forest districts in Austria, Belgium, France and Germany (Beil, 1839; Kapp, 1984). When industrialisation made labour more expensive and agronomic progress allowed to restore and maintain soil fertility without having to recur to reforestation, European agroforestry practices started to decline (Kapp, 1984). Trees were increasingly banned from agricultural land. This is mainly due to agricultural mechanisation that is linked to the pressure for increased labour productivity, to land re-allocations in the process of consolidations of fragmented holdings and to increasing specialisation of the farming enterprises (Herzog, 1998).

Arable *Streuobst*[2] in Germany

For farmers the combination of arable crops and fruit trees was of particular interest. In fact, the expansion of fruit production which occurred in the 19th century was only possible because these trees could be integrated in their farm and did not impede the rotation (Lott, 1993). Basically, rows of standard fruit trees were planted at different distances (Figure 6), distances were wide enough for crop production to dominate. This fundamental scheme, which was to remain valid for about a century, was varied in numerous ways: high and low stem trees could be altered within the rows, different types of

[2] defined as “tall trees of different types and varieties of fruit, belonging to different age groups, which are dispersed on cropland, meadows and pastures in a rather irregular pattern” (translated from Lucke et al., 1992, p. 10)

arable crops from cereals, root crops to vegetables, strawberries, etc. were chosen, often fruit trees were also combined with berry production on bushes (currant, gooseberry, etc.). Arable undercropping was the pre-condition for the extension of fruit production: farmers would have uprooted the trees immediately if they would have had to abandon undercropping (Lott 1993, p. 98) and specialised fruit production was not possible because of the long period without fruit yield which had to be overcome. Apparently there was a conflict between scientists which aimed at improved and maximised fruit production and therefore recommended to restrict undercropping and farmer organisations which in 1910 reproached „the otherwise quite good specialists, who think that commercial fruit production cannot be combined with undercropping, are not able to calculate“ (Lott 1993, p. 100). It seems that the specialists lacked an appreciation of this agroforestry system and were biased towards increasing fruit production whereas farmers had a more comprehensive understanding and tried to optimise the overall financial return.

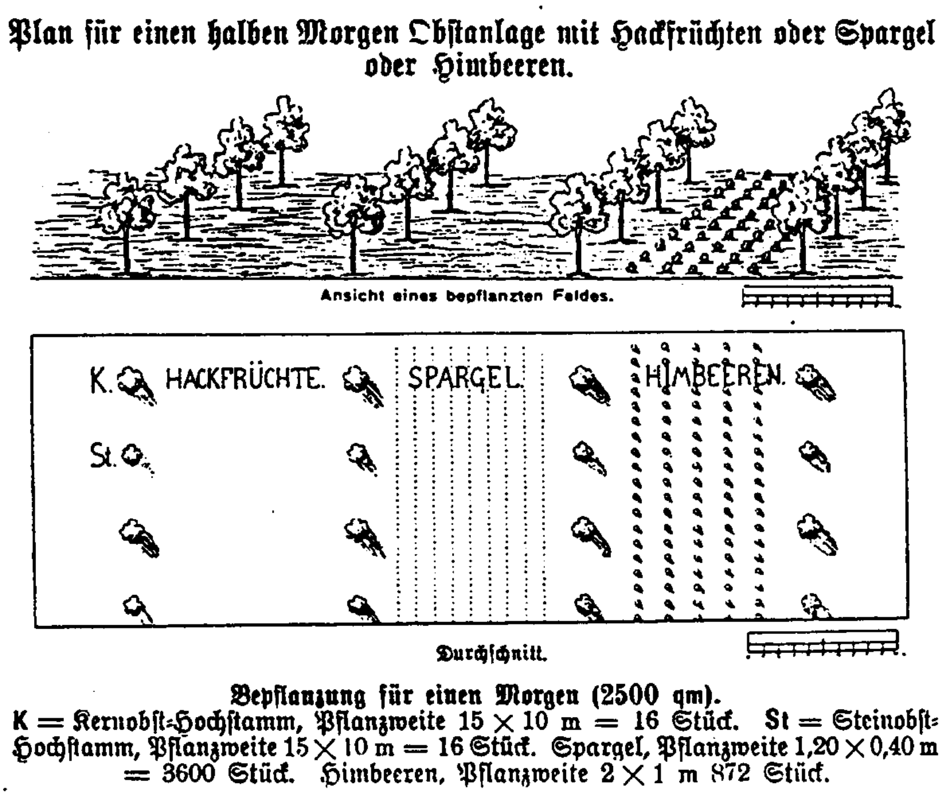


Figure 6. “Plan for a fruit orchard of one morgen with root crops or asparagus or raspberry” In the tree lines pomme fruit (“K”) and stone fruit (“St”) are alternated, tree planting distance is 15 x 10 m (from Lott, 1993, Fig. 12, Reference 229). Similar plans exist for combinations with strawberry, currant, etc.

From the fruit tree statistics of 1938 it can be assumed that in the 1930s there were about 800'000 hectares of (mostly silvo-arable) *Streuobst* in the German Reich of that time (relating to the boundaries before the second World War, SRA 1940)[3]. In a review Trenkle (1944) examined the impact of

[3] 78.9 $*10^6$ fruit trees, assuming 100 trees per hectare. In addition 110 $*10^6$ fruit trees in home gardens were counted which were often also underplanted.

understorey crops in fruit orchards on the nutrient and water balance and on the yield of the fruit trees. In the 1940s fruit production was mainly in the hands of small family farms which had to combine fruit and arable production in order to guarantee subsistence and sufficient fodder production for farm animals. Therefore fruit tree lines were distant enough to allow for cropping. These crops were part of the normal rotation which usually consisted of cereals, root crops (potatoes, sugar and fodder beet), vegetables, clover and grass. Trenkle (1944) insisted on the competition for water and nutrients, especially between May and July, which may reduce fruit production. Competition was judged higher with cereals, deep tooting clover and grass whereas root crops and vegetables were considered less demanding during that period and were seen to improve soil structure (provided sufficient availability of fertiliser). Trenkle (1944) concluded that in regions of lower rainfall (bellow 700 mm per year) undercropping should be abandoned, trees should be spaced more closely and only undercropped with root crops during the first years after planting. In regions with higher rainfall (above 850 mm per year) trees may be underplanted with grass. This may even be advantageous for wood production and quality because of the high evapotranspiration in autumn.
Trenkle (1944) examined competition between fruit trees and crops from the point of view of fruit production. His approach is opposite to the one of Wahlen and Gisiger (1937) who estimated the annual loss of fodder production (quantity, quality) due to fruit trees on grassland in Switzerland at about 15 – 20 Million Swiss Francs. In neither of the two articles the total productivity of the system was assessed although Trenkle (1944) recognised the socio-economic justification for combining trees and crops (small holdings, scarcity of land, high share of subsistence).
At the Berlin University the interactions between fruit trees and understorey crops were examined systematically in field experiments. Schulz (1936) presented results from the experimental years 1932 and 1933, they are summarised on the following pages.

The Berlin experiments (Schulz, 1936)

Schulz (1936) conducted field experiments on silvo-arable agroforestry using stands of mature pear and apple trees in Berlin Dahlem. The trees were 25-30 years old, the experimental design in the pear orchard and in the apple orchard is shown in Figure 7. Control plots (no trees) were 70 to 300 m from the trees. The soil was relatively uniform with water holding capacity of about 28%, pH around 7.4.

Half-standard pear trees, 5 x 5 m, 6 sqm per plot / 20 sqm per plot

Standard apple trees (Sch.v.Boscoop), 9 x 10 m, 30 sqm per plot

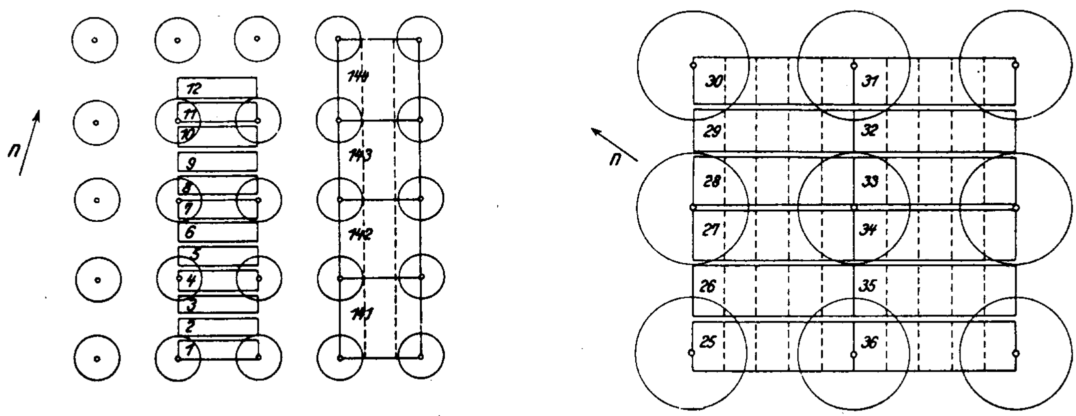


Figure 7: Experimental design in pear and apple plantations (Schulz, 1936, Fig. 11, 12)

1. Pear plantation (5 x 5 m), kohlrabi on plots of 6 sqm

Yields were between 64% (1st harvest) and 33% (2nd harvest) as compared to the control plots. This is mainly explained by the reduced availability of light (Figure 8). Plots were irrigated and sufficiently fertilised to exclude competition for these factors. In addition there was a control with artificial shading by covering the crops with textiles. Yields under artificial shading roughly corresponded to yields in the agroforestry plots.

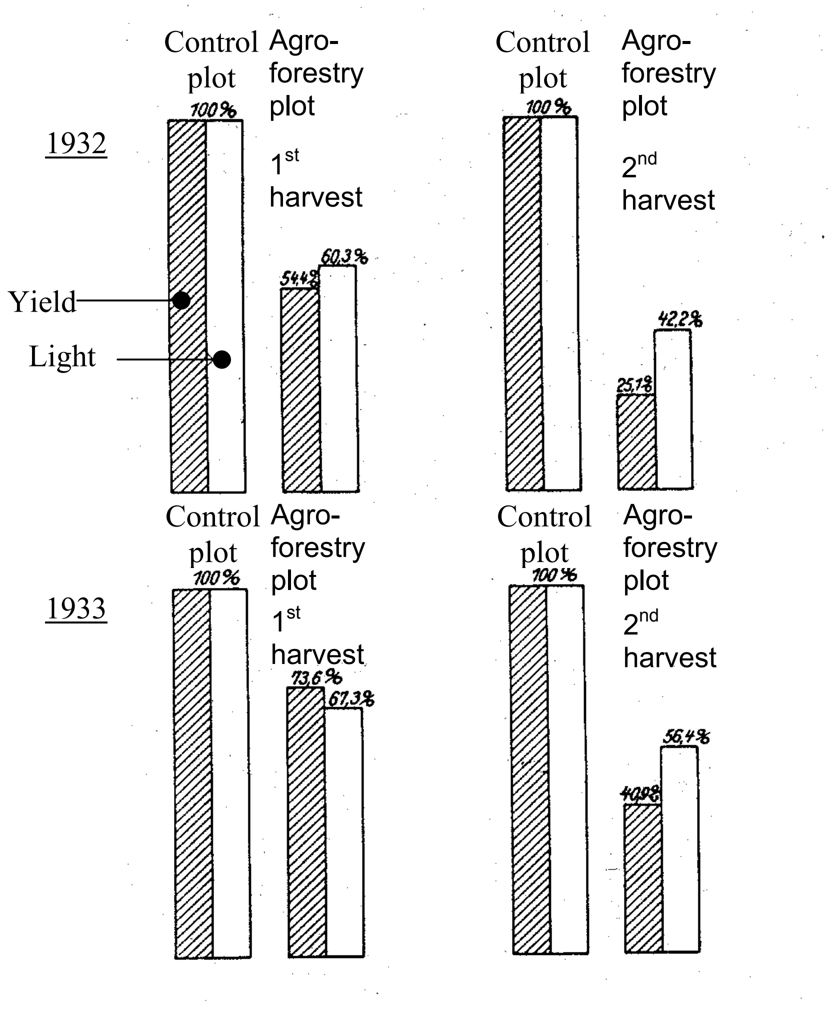


Figure 8 . Yield of kohlrabi and light intensity in unshaded control plots (100 %) and in agroforestry plots (pear plantation) compared to the control in two subsequent years (Schulz, 1936, Fig. 19).

2. Pear plantation (5 x 5 m), head lettuce on plots of 6 sqm

Yields were at 53% as compared to the control plots, again the proportion of light and yield reduction was similar. The quality of the lettuce was strongly reduced: the share of premium quality lettuce from the agroforestry plot was only 1.5% (1^{st} year) and 17.2% (2^{nd} year) as compared to the control plot where 79.3% (1^{st} year) and 87.6% (2^{nd} year) could be sold on the market.

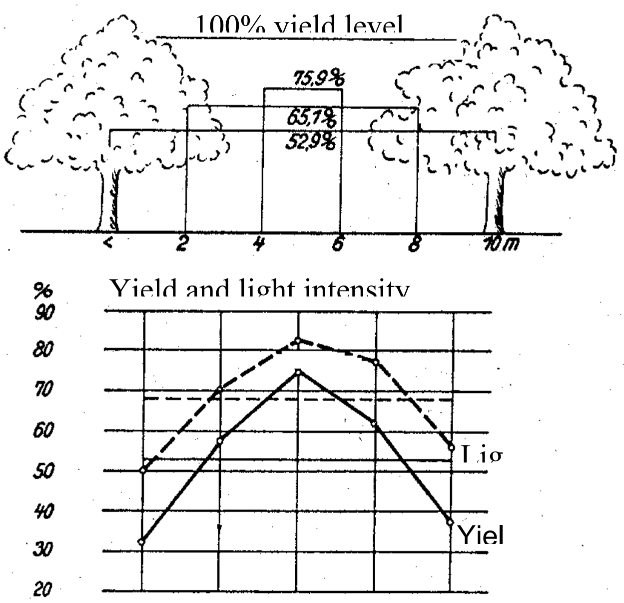
3. Apple plantation (9 x 10 m), bush bean, knob celery, white cabbage on plots of 30 sqm

Yields were reduced by around 50% as compared to the control (Table 15). Again the reduction is explained by the reduced availability of light.

Table 15. Vegetable yields of control and agroforestry plots (Apple trees, 9 x 10 m) (Schulz, 1936, collated from Tables 37a, 37b, 37c).

	Agroforestry plot		Control	
	kg	%	kg	%
Bush bean	30.81	53	58.32	100
Knob celery	28.90	54	53.10	100
White cabbage	130.05	47	278.40	100

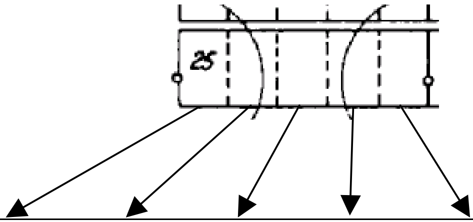
Figure 9. Impact of apple trees (9 x 10 m) on light intensity and yield of bush bean at different distances from tree row (Schulz, 1936, Fig. 21)



The plots of 30 sqm were subdivided in 5 sections of 2 m width each which reflect different distances from the tree row. Yield as well as light availability were recorded individually. This allowed to assess the impact of different distances from the tree row. As an example yield and light availability for the bush bean experiment are shown in Figure 9.

The possible reasons for reduced yield under trees were examined (Table 16):

- light: there clearly was a parallel development of light availability and yield (Figure 9).
- water: in the top layer of the soil there was no real difference in water availability between agroforestry and control. About 13% (26 mm) of the precipitation was intercepted by the tree crowns (Table 16). Schulz (1936) concluded that differences in water availability cannot be the major cause for yield reduction under agroforestry although he acknowledged that he did not test water availability bellow 25 cm.
- temperature: temperature was more equilibrated in the agroforestry plot but daily minimum and maximum temperatures differed only by about one degree Celsius. It was concluded that this could not explain the strong reductions of crop yield.



	Agroforestry plot						Control
	2 m	2 m	2 m	2 m	2 m	Average	
Yield: relative yield [%]							
	33.9	65.0	84.7	56.5	31.1	54.3	100
Quality [% of total harvest]							
Premium quality	57.3						93.2
Light: Relative intensity of light [%]							
	48.2	68.2	83.8	73.6	53.3	65.7	100
Water: Relative humidity in top soil [%]							
31. May	10.8	12.8	12.1	14.7	12.6	12.6	11.1
24. June	15.4	18.1	15.3	17.5	16.0	16.4	17.1
29. August	9.9	11.8	9.9	13.0	10.1	10.9	10.7
21. September	8.6	9.0	9.3	11.6	9.6	9.6	9.8
11. October	9.3	9.5	9.6	11.3	10.1	10.0	9.4
Water: precipitation measured at soil level, total of June – August [mm]							
	190.9	169.5	213.5	193.2	201.5	190.8	217.5
Temperature: average daily minimum and maximum temperature from May to September [°C]							
Minimum	10.9						10.3
Maximum	24.4						25.4

Table 16. Values for yield, quality, light, water and temperature availability in the knob celery plots under agroforestry (apple trees) and in the unshaded control in 1933 (collated from Schulz 1936, Tables 39b, 40, 41, 42, 44). The agroforestry plots between tree rows were subdivided in sections of 2 m. See Figure 7 for the experimental design.

From these data Schulz (1936) concluded that in the agroforestry systems he investigated the observed reduction of yield is mainly caused by the reduced availability of light. He confirmed this by a parallel experiment where shading was provided by textiles and which resulted in similar values as the agroforestry plot.

4. Potatoes and undercrop

In both plantations (pear and apple) experiments with potatoes (and onions) were conducted. The potatoes („Holländischer Erstling“, a variety of early potatoes) were planted at distances of 50 x 50 cm in the same experimental design as described above. Again there was a parallel evolution between yield and light availability which increased with increasing distance from the trees. Compared to the control, the average potato yield in the agroforestry plot was 39.6 % (pear trees, 5 x 5 m) and 45.3 % (apple trees, 9 x 10 m), respectively (Figure 10).

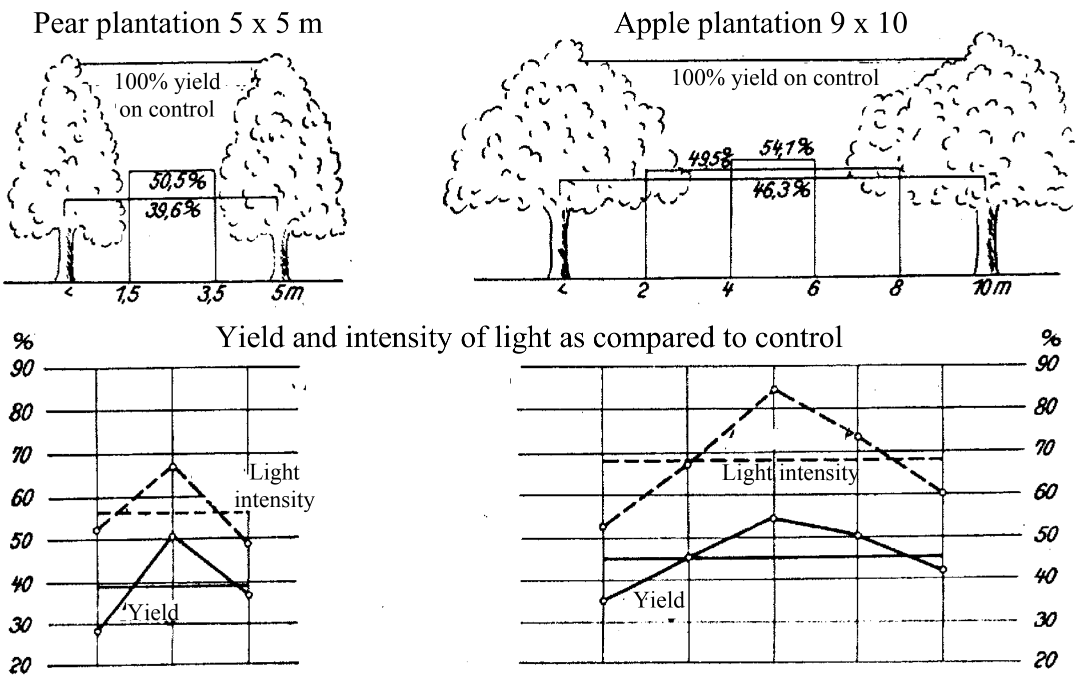


Figure 10. Relative yield and light intensity of early potatoes under pear trees (5 x 5 m) and apple trees (9 x 10 m) as compared to a control plot without trees (Fig. 24 in Schulz, 1936).

In addition to the reduction in yield, the potatoes' starch content under agroforestry was 13-20 % lower than in the control plot.

5. Conclusion

The reduced availability of light was identified as the main factor for the reduced yield (and quality) of understorey crops in an agroforestry setting as compared to open plantings, followed eventually by water stress as the 2nd most important factor. Schulz (1936) discussed his results in the context of the literature of his time (mainly from the US, the UK and France). The observed yield reductions differed quite significantly from earlier published indications of yield reduction (e.g. Janson, 1924). These, however, were not based on experiments but resulted from general experience and observations.

Schulz (1936) repeatedly pointed out the difficulties of agroforestry experimentation which either requires long term experiments over several decades or has to use existing tree plantings which eventually do not allow for an optimum experimental design. In his experiments the main drawback of the existing plantation was that tree distances were rather low (5 x 5 m for pears) which clearly limited the possibilities for cropping. From other literature (e.g. Lott, 1993) it can be concluded that farmers generally used larger spacings.

Present time silvo-arable agroforestry in Germany

Whereas silvo-arable agroforestry with forest tree types had been abandoned already in the 19th / early 20th century, silvo-arable *Streuobst* persisted until the 1950s. Then it was abandoned as well due to the development of intensive fruit production with dwarf trees and to large scale mechanisation of agricultural crops.
In eastern Germany, however, there was an interesting exception. When farmers were forced to join agricultural co-operatives they were allowed to keep only small plots of land for their own purpose. On some of these plots the ancient silvo-arable *Streuobst* revived. Undercropping of cherry trees (*Prunus avium*) mainly with turnip (*Beta vulgaris*), but also with alfalfa (*Medicago sativa*), potatoes (*Solanum tuberosum*) and oat (*Avena sativa*) is still practised by a few farmers up to today for household consumption (Photo 14).

Relevance for SAFE

The experiments of the first half of the 20th century are of general interest for the SAFE project because they address the topic which is also at the centre of SAFE: interactions between trees and crops, impact on yield, identification of limiting factors. Of course the technology was less advanced. On the other hand, Schulz (1936) made his trials in fully developed stands of trees. Unfortunately the crops he examined – except for potatoes – differ from the crops which are investigated in SAFE.

Reading these historical articles with the today's point of view it is interesting to observe that none of the authors tried to examine the entire system. They concentrated on either the crop or on the trees. It is not surprising, therefore, that most authors come up with more drawbacks than advantages (trees reduce crop yield, crops hamper tree management and reduce fruit yield). In contrast, farmers seem to have had a more comprehensive point of view of optimising (financial) yield by combining the two components.

The following observations are of particular interest for SAFE:

- yield reduction of crops in fully developed agroforestry stands may be significant, they were around 50% in the Berlin experiments (Schultz, 1936) – although at rather narrow tree spacing;
- not only the quantity but also the quality of the crop's yield may be reduced; if possible this must be considered in the economic model;

- deep rooting crops (grass, clover, cereals) were considered less suitable than root crops which improve soil structure;
- light and water were identified as the major limiting factors;
- in humid regions intercrops (or grass) were considered beneficial for the "ripening" of the wood due to the increased evapotranspiration in autumn;

Based on a refined literature search more quantitative information could be gathered from historical long term experiments and from experiments in fully developed agroforestry plots. They might be used for plausibility checks of the HySAFE model.