CONCEPT PROPOSAL FOR A LONG-TERM MONITORING OF RESIDUES FROM PLANT PROTECTION PRODUCTS IN SOIL

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1 Management summary

Plant protection products (PPP) have been applied to field crops and permanent cultures in Switzerland regularly for decades now. With increasing knowledge on the effects of long-term exposure to PPP residues on humans, the environment in general and the soil quality in specific the general concern has risen. Consequently, an Action Plan for Risk Minimization and Sustainable Use of Plant Protection Products (AP PPP) was developed with the goal to reduce the risk from use of PPP by 50%. This Action Plan includes a concrete measure to fill knowledge gap concerning PPP residues and their transformation products in the soil. This Measure 6.3.3.7 “Developing a monitoring of PSM-Residues in soil” builds the basis for this project and requests to develop a program to monitor PPP residues in soil.

Pesticides have long been monitored in surface- and groundwater. However, so far there has been no comprehensive inventory of PPP residues in soil, let alone any long-term monitoring. Furthermore, it is unknown which impact the combination of PPP residues have on soil quality, which are the risk drivers and how we can reduce the risk by half as demanded by the AP PPP.

To fill the knowledge gap concerning PPP residues and their transformation products in soil, we will first define a list of relevant compounds. Under consideration of high-risk substance as defined in the AP PSM, we will select them based on the following criteria: eco- and toxicological relevance, persistence in soil, bioavailability, amount and frequency of usage, analytical determinability and stakeholder interest. Preceding this project, Agroscopes’ Environmental Analytics Group and NABO have already established a multiresidue method to facilitate a cost effective chemical analysis of a number of substances and successfully tested it on NABO sites. This method will now be optimized and extended to cover the above mentioned list of relevant substances. While the NABO already monitors soil properties on a wide selection of sites, we will extend the selection to have a sample set representing the most PPP intensive land-use forms, orchards, vineyards and vegetable growing, with a sample large enough to reach statistical significance. In a core work package, using the NABO site selection we are focusing on evaluating and modelling fate of PPP residues according to management data and developing the analytical multi-residue method. Next to the core work package, we will look into various specific questions in separate thematic work packages designed to provide a comprehensive inventory on spatial and temporal variability of PPP residues in intensively agricultural soils in Switzerland. The goal is to complement the existing collection of sites and the current sampling strategy, to then propose a concept for a long-term exposure monitoring of PPP residues in Swiss agricultural soils. In parallel, we will develop indicators and reference values to determine the impact of PPP residues on soil quality and propose measures to reduce the risk to the soil quality.

This concept proposal outlines in more detail which steps we already have taken and which further steps we will take to reach the above outlined goal.

2 Introduction

Plant protection products (PPP) have been applied to field crops and permanent cultures in Switzerland regularly for decades now. With increasing knowledge on the effects of long-term exposure to PPP residues on humans and the environment in general and the soil quality in specific the general concern has risen. Consequently, the list of substances banned due to environmental or human safety concerns becomes longer. However, the Swiss agronomist can still choose from a list of approximately 250 chemical synthetic active ingredients (a.i.). Many of which reach the soil after their application because of wash-off, drift or incomplete plant interception. In the case of seed treatments, they are introduced into the soil directly. Unsurprisingly, it becomes more and more evident that agricultural soils host a sheer cocktail of chemical synthetic PPP residues, made out of active ingredients and their transformation products, many of which remain in the soil for long time-periods.

Although the above outlined scenario is by no means a new finding, actual measurement based information on long-term fate and behavior of PPP residues in the soil under real world field conditions is rare. The current risk assessment for in-soil organisms is carried out according to the SANCO/10329/2002 Terrestrial Guidance Document developed under the Council Directive 91/414/EEC. While producers of PPP need to show that acute and chronic risks to the soil organisms are acceptable before they can sell any PPP in Switzerland, they need to do so only for their specific product. The tests, which the authorities prescribe for this purpose, are highly standardized experiments mostly conducted in a laboratory environment and in four different types of soils only. These tests only partly reflect the complexity of the natural environment. The soil with its multiple phases and various ecosystem service functions is an especially complex matrix. Just this complexity is in part responsible for the lack of appropriate analytical methods to quantify the vast amount of different a.i. and their transformation products possibly present in the soil, which then precluded a broad soil monitoring of PPP residues in the like of ground and surface water monitoring programs. Recent advances in multiresidue extraction and analytics have opened up new possibilities in soil exposure monitoring with justifiable economical efforts.

In 2003, the Federal Council of Switzerland propagated that with regard to the environmental risk of fertilizers and PPP ‘’… the long-term effect on soil organisms have to date been studied only insufficiently. Therefore, developing indicators for estimating the effect of PPP on the soil quality has a high priority.” In the later audit report of 2009 (Report with regard to Postulate UREK-SR 03.3590, BAFU 2009) the Federal Council came to the conclusion that there is still a need for action regarding the reduction of environmental risks caused by PPPs. In this report, the situation analysis deals in detail with the condition of the Swiss ground and surface waters, but not with the condition of the soil, although this was originally requested in the postulate of the Federal Council in 2003 (UREK-SR 03).

Because of the Postulate 12.3299 (Moser, 2012) for an "Action Plan for Risk Minimization and Sustainable Use of Plant Protection Products" in 2012, the Federal Council decided to draw up an interpretation ordinance for the measures (Bundesrat, 2014). The draft of the clarification of demand (Bedarfsabklärung) initially included a number of measures in the aquatic area, but not for the soil. At the initiative of the Swiss National Soil Monitoring Network (NABO), Chapter 4.5.4 PPPs in soils was introduced to the report and highlighted the large knowledge gap on potential risks in soils.

In the later development of the “Action Plan for Risk Reduction and Sustainable Use of Plant Protection Products” (AP PPP, Bundesrat 2017), four thematic working groups were formed under the auspices of the Swiss Federal Office for Agriculture (FOAG) in the spring of 2015, including the Working Group on Soil & Non-Target Organisms. NABO supported the technical direction of this working group and summarized the results in a final report (AG Boden 2015). In the draft of the AP PPP consultation, the following main soil-fertility objective was defined: "The use of PPPs has no long-term detrimental effects on soil quality and the use of material with potentially high risk is reduced". In comparison with other environmental areas, the knowledge gaps regarding the risk of PSM residues in the soil are still very large; correspondingly high is the demand to close these gaps.

Consequently, in the final version of the Action Plan, the authors concretized the main soil-fertility objectives (Goal 5.7 “Protection of soil quality” in AP PPP) to:

> 1) fill the knowledge gap concerning PPP residues and their transformation products in the soil
>
> 2) reduce the use of those PPP containing a.i. with degradation half-life longer than 180 days by 50 % until 2027 compared to the period from 2012 – 2015

For both goals, the AP PPP defines an individual measure. Measure 6.3.3.7 “Developing a monitoring of PSM-Residues in soil”, which is the basis for this project, focuses on the first goal and accordingly requests to develop a new program to monitor PPP residues in soil. Moreover, measure 6.3.3.7 demands that indicators to assess effect of PPPs on soil quality are necessary. Indeed, the effects of PPPs on soil organisms and on soil processes are assessed during the registration phase. After PPPs have been placed on the market, no further monitoring data are required and nearly no effect data (i.e. ecotoxicity data) are therefore available to be compared with the data obtained from the PPP registration phase. The goal will thus be to develop and implement existing suitable effect indicators for such a purpose. The feasibility of developing reference values based on risk for PPPs active ingredients in soil must also be evaluated.

Other measures, e.g. Measure 6.3.2.6 (“Indicators for the monitoring of potential risk of PPPs for organisms”), Measure 6.3.2.5 (“Risk assessment development in regard to terrestrial non-target organisms”) and Measure 6.3.3.6 (“Evaluation of the implementation of emission reduction and risk measures for non-target organisms and surfaces close to the natural state”) are also dealing to a certain extent with risk or effect indicators to assess effects of PPP on soil organisms and soil quality. Synergies between these measures and Measure 6.3.3.7 will be considered and developed in this context.

In 2018, the NABO was mandated to prepare a concept outlining the steps necessary for establishing a long-term monitoring of PPP residues in soils. In the course of the preparatory work, we organized two workshops with national and international experts, each with very fruitful outcomes. (Please find the minutes of both workshops in the appendix.) Ecotoxicology experts from the Ecotox Center and EnviBioSoil were mandated to give support and orientation during these two workshops, to identify the gaps and needs regarding the existence or feasibility to define Environmental Quality Standard (EQS) for PPP in soil, and accordingly to perform a first literature review providing an overview of the current state of the art regarding risk assessment and available bioindicators to evaluate the effects of PPP on soil organisms. The present draft concept is a result of the outcome of the above-mentioned workshops combined with knowledge gained from literature review, previous pilot studies and studying similar projects ongoing in other countries.

3 State of the art

3.1 PPP residues in soil

3.1.1 Fate and behavior of PPP residues in soil[1]

Before an active ingredient (a.i.) is allowed market access to the EU and Switzerland, registrants need to also provide data on the fate and behavior of PPP residues in soil on a minimum of four different soils, which must represent the conditions of the anticipated use (EC 2009). Resulting endpoints such as the degradation half-life in soil (DT50soil) or the organic carbon/ water distribution coefficient (Koc) are mostly based on highly standardize laboratory studies and are used to estimate predicted exposure concentrations in the soil (PECsoil). These and the above-mentioned endpoints are then part of the registration dossier. In an aggregated form, they are publicly available in the so called "EFSA conclusions", which are peer reviews of the pesticide risk assessment. Outside the registration process, the majority of studies published on environmental fate of PPP residues in soil, published between 1990 and 2016, are laboratory studies. While for some substances the amount of research clearly reflects the high public interest, information on others is scarce. The fate and behavior of 2,4-D for example has been well studied in a vast selection of soils from Canada (Picton et al. 2004, Farenhorst et al.2010, Farenhorst et al.2008, Gaultier et al. 2006, Gaultier et al. 2007) Brazil, South Korea, Costa Rica, the US (Dubus et al. 2001, Hyun et al.2005), Spain (Rodriguez-Rubio et al.2006, Villaverde et al.2008), France (Kah et al.2007, Kah et al. 2007b, Boivin et al. 2005) and the Slovak Republic (Hiller et al.2008). Other substances, studied by a larger number of authors, are Glyphosate (Baez et al. 2015, Okada et al. 2016, Sorenson et al.2006, Al-Rajab et al. 2010, Mamy et al. 2013, Mamy et al. 2005; Mamy and Barriuso 2005, Dousset et al. 2004 and Dousset et al. 2007) and Isoproturon (Vallée et al. 2014, Bending et al. 2006, Perrin-Ganier et al.2001, Nemeth-Konda et al.2002, Charnay et al.2005, Larsbo et al.2009, Alletto et al. 2006, Boivin 2005). A high leaching potential seems to motivate more soil fate and behaviour studies than a high soil accumulation potential. An example for a well-studied substance with a high leaching potential is MCPA (Hiller et al. 2009, Haberhauer et al. 2001, Hiller et al. 2010, Jensen et al. 2004, Vallée et al. 2014, Sorenson et al. 2006, Hiller et al. 2006 and Hiller et al. 2008; Methsulfuron-methyl: Villaverde et al. 2008, Ismail et al. 2002, Ismail et al. 2012, Baez et al. 2015, Kah et al. 2007; Kah et al. 2007b and Sondhia et al. 2009; or Imidacloprid: Oliver et al. 2005, Nemeth-Konda et al. 2002, Scorza Junior et al. 2004 and Sarkar et al. 2001). Diflufenican, which has a rather high potential for soil accumulation, however is much less studied (Bending et al. 2006; Napropamide: Vallée et al. 2014; or Pirimiphos-methyl: Patakioutas et al. 2002). The number of laboratory studies outside the registration dossier, focusing on fate and behavior in soil of substances defined as "soil persistent" in the AP PPP is limited. Such studies are only available for Bromuconazole (Jamet and Cornejo 2000), Diquat (Pateiro-Moure et al. 2007 and 2010), Fluxapyroxad (Li et al. 2014 and 2015, Gulkowska et al. 2016), Lufenuron (Zheng et al. 2009 and Guo et al. 2011), Myclobutanil (Yu et al. 2006). For Thiabendazole only less recent studies are available (Aharonson and Kafkafi 1975 and Solel et al. 1979), most of which do not give DT50 or Koc values.

Field studies on environmental fate properties are under EU regulation only triggered for registration purposes where there is a suspicion of persistence (DT50 lab >60 days or DT90lab >200 days). Field monitoring is at times employed when PEC groundwater estimated for an a.i. exceed the required trigger value of 0.1 µg/L and its toxicological non-relevance cannot be shown. In this case, the degradation time or mobility of the substance need to be assessed on four or more representative sites in different geographies (EC 2013). In research outside the regulatory scope, very few a.i. have been studied on such a variety of soils and geographies. If so, studies are mostly conducted by

[1] The literature outline in this chapter is based on a literature overview kindly provided by M. Lebrun, FOEN.

different authors without commitment to a particular common methodology between the authors. This makes the results difficult to compare, since extraction and detection methods can vary. Of the 34 approved a.i. for which we found literature on field studies, only six have been studied on four or more soils: Dioron (Rouchaud et al. 2000, Alister et al. 2010), Glyphosate (Al Rajab et al. 2008, Bergstrom et al. 2011, Laitinen et al. 2009, Laitinen et al. 2006, Grundmann et al. 2008), Isoproturon (Vallee et al. 2014, Grundmann et al. 2008, Coquet et al. 2004), Metamitron (Coquet et al. 2004), Picloram (New Zealand, Close et al. 2003), and Terbuthylazine (New Zealand, Close et al. 2003). Of these a.i. studied on four or more sites only some are done by the same author. These are Glyphosate (Finnland: Laitinen et al. 2006, France: Al Rajab et al. 2008), Metamitron (France, Coquet et al. 2004), Picloram (New Zealand, Close et al. 2003), Isoproturon (France: Coquet et al. 2004), Terbuthylazine (New Zealand, Close et al. 2003). However, often soils are of similar type and texture, and pH values only cover very narrow ranges, e.g. pH 5.9 – 6.4 for studies done on Glyphosate (Laitinen et al. 2006) and thus do not meet the requirement of a broad representativeness. With respect to field derived parameter values, we conclude that both public and regulatory databases lack completeness, whereby the regulatory databases per obligation meet the requirement of broader geographical representativeness.

3.1.2 Monitoring of PPP residues in soil

Although monitoring of pesticides in the ground and surface water is an integral part of national environmental monitoring (BAFU, 2009), soil monitoring campaigns that go beyond a regional scale and a small selection of PPP residues and their transformation products (henceforth collectively called PPP residues) are scarce. Internationally, the countries with the largest projects are the USA (Carey et al., 1979), Spain (Fernandez-Alvarez et al., 2010, Gamon et al., 2003, Martinez Vidal et al., 2010), Korea (Park et al., 2013), Hungary (Mortl et al., 2010, Szekacs et al., 2014) and most recently the Czech Republic (Hvesdova et al. 2018, Vasickova et al. 2018). Other less comprehensive studies with regional to national scope, mostly focusing on organoclorine pesticides or substances already forbidden in Switzerland, have been done for example in Thailand (Thapinta and Hudak 2000), India (Yadav et al. 2015), Saudi Arabia (Al-Wabel et al. 2011). Other examples are studies on soils from East Europe and Central Asia (Lozowizka et al 2016), Serbia (Markovic et al. 2010) or Brazil (Rissato et al. 2006).

The PPP monitoring in the Czech Republic is one of the very few which goes beyond a once in time sampling campaign and incorporates annually repeated measurements (Hvesdova et al. 2018, Vasickova et al. 2018). In an EU wide study, PPP residues in soils from various NUTS 2[2] regions a were measured (Silva, 2018). These two studies established multiresidue extraction and detection methods to measure a vast selection of more than 50 modern compounds. Arable soils in the Czech Republic as well as those from the various NUTS 2 regions contained mixtures of compounds, however in very varying combinations (Hvesdova et al. 2018 and Silva, 2018). None of the studies assessed typical combinations of PPP residues, characteristic for specific types of land-use or particular regions.

In Switzerland, several isolated studies on PPP residues in the soil were conducted. On a national scale, NABO has taken first steps to fill the data gap by measuring PPP residues on the NABO monitoring sites (Chiaia-Hernandez et al. 2017). In a pilot study, 80 a.i. and more than 90 transformation products were targeted in archived topsoil samples (Chiaia-Hernandez et al. 2017). The samples originated from 29 sites with 12 sites on cropland, two vegetable growing sites, seven orchards and eight vineyards. The results show that concentrations and number of compounds vary

[2]NUTS Nomenclature of Territorial Units for Statistics, French: “Nomenclature des unités territoriales statistiques”, NUTS 2 are territorial units on provincial level.

strongly between crop types and between fields (**Figure 1**). In contrast to PPP residue studies elsewhere, at NABO we also have exact multiyear PPP application records for each plot available. In orchards and vineyards, the number of PPP residues found in soils match or are lower than the number of PPP applied per year. This is because, on permanent cultures, the pests and diseases are similar from year to year and thus variability in choice of PPP indicated for those pests and diseases is small. On cropland however, the crops change from year to year and so does the indicated choice of PPP. This, in combination with the fact that most PPP residues remain detectable in the soil for more than one year, results in that the number of PPP residues detected in cropland soils is usually higher than the number of PPP applied per year.

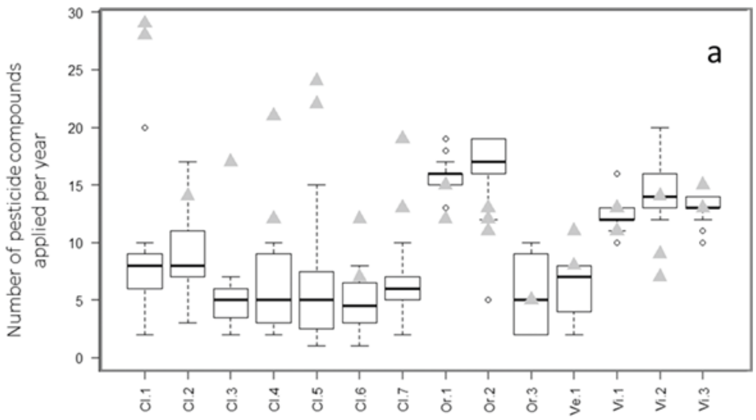

FIGURE 1 BOXPLOTS SHOWING NUMBER OF PPP APPLIED PER YEAR IN RELATION TO LAND USE, TRIANGLES ▲ SHOWING NUMBER OF PPP RESIDUES FOUND IN SOIL (CL = CROPLAND, OR = ORCHARDS, VE = VEGETABLE, VI = VITICULTURE) (CHIAIA-HERNANDEZ ET AL. 2017)

Since the publication of the pilot study, the NABO initiated one additional measurement campaign at national scale (Screening 1), which we are currently evaluating. On a cantonal scale, the canton Basel-Landschaft has published a status report on organochlorine pesticides (OCP) in Baselbieter soils in which they analyzed the OCP contents in 71 different soils (Schmutz et al. 2011). More recently, the canton of Thurgau and IP Suisse were initiating research on PPP residues in the soil as part of larger research efforts on PPP residues in the environment (personal communication L. de Baan, 2018). Most recently, members of Bernese Plant Protection Project have signaled their interest in analyzing PPP residues in soils in their research (personal communication D. Füglistaller, 2018). Still, so far in Switzerland no comprehensive approach with standardized methodology has been performed to fill the knowledge gap on PPP residues in soils.

3.2 Analytical methodology

The organic trace analytical laboratory of the Agroscope Research Group "Environmental Analytics" adapted and validated an analytical method originally established by Chiaia-Hernandez et al. (2017). The method allows quantifying 38 pesticides (14 Herbicides, 17 Fungicides, seven Insecticides) and eight of their metabolites in soil in the µg/kg-concentration range. Target analytes were selected based of a series of criteria, such as their chemical-physical properties, application frequency and amount, and positive detects in Chiaia-Hernandez et al. (2017). Pesticides are extracted from soil at elevated temperature (65 – 120 ºC) and pressure (110 – 130 bar) with accelerated solvent extraction (ASE) and two different solvent compositions (1: acetone/methanol/acetonitrile (65:10:25%), 2: acetone/water (1% phosphoric acid) (70:30%)). Analyte separation takes place on a Phenomenex Kinetex 5 µm, Biphenyl A 100A column (100 x 4.6 mm), using a water – methanol gradient in presence of an ammonia acetate buffer. The pesticides are ionized in positive and negative electrospray mode (ESI+/ESI-), and detected with triple quadrupole mass spectrometry. Two parent-daughter ion transitions are used per analyte. The method includes 23 isotope-labelled internal standards to compensate for matrix effects (ion suppression) and increased robustness. Method precision for most analytes in various soils was <10%, and recoveries of a majority of the pesticides were between 80 and 120%. Detection limits as quantified by signal-to-noise ratios of three in presence of soil matrix ranged from 0.05 to 1.0 µg/kg.

Please note that there is, to the best of our knowledge, no generally established reference method for multiresidue analysis of modern pesticides in soils available from any of the international standardization organizations such as the International Union of Pure and Applied Chemistry (IUPAC), the International Organization for Standardization (ISO), or the Association of Analytical Communities (AOAC International). International existing guidance documents promoting and setting standards for multiresidue analytics are intended for post-registration of maximum residue levels in foodstuff and animal feed (OECD 2007, Sanco 2006, Sanco 2004, Codex 1993, US EPA 1996 and PMRA 1998) and are thus not suitable to guide multiresidue analytics of PPP residues in soil. Researchers in the field of multiresidue analytics in the soil this far all used individual methodological approaches not yet internationally harmonized. Because most of them are based on the QuEChERS extraction (e.g. Hvezdova et al. 2018, Lozowicka et al. 2017, Pszczolinska & Michel 2016), we compared this method with the one by Chiaia-Hernandez et al. (2017) described above.

An inherent limitation of all multiresidue analytical methods is the fact that a set of chemically-physically more or less diverse target analytes is extracted with one extraction solvent (mixture), which is designed to work well for a majority of the compounds, but may not be well suited for extreme endmembers. In the case of the currently analyzed 38 pesticides, this is manifested by the fact that the above described extraction method quantified on average higher concentrations that a more generic QuEChERS-approach (e.g. Pszczolinska & Michel 2016), while the latter may still be superior for selected individual compound (classes), e.g. phenylurea herbicides, at least in some soils (Table 1). Conversely, our method yielded consistently higher extractable concentrations for triazines, and neonicotinoids. Note that the relative performance of different extraction methodologies varied from soil to soil. Mechanisms and influencing factors (e.g. total organic carbon content, TOC) are yet to be investigated. In consequence, any expansion of the target analyte list will require a critical evaluation and optimization of the analytical method.

Table 1 Performance of QuEChERS extraction for different pesticide classes relative to the one by Chiaia-Hernandez et al. (2017) from five different soils from the NABO (own unpublished data)[a]

Soil sample No.	1	2	3	4	5
TOC [%]	2.0	13.5	1.5	2.0	1.6
Triazines (n<=4)	46±13%	26±2%	27±18%	36±9%	25±34%
Phenylureas (n<=3)	142±49%	104%	34±31%	59±37%	110±3%
Neonicotinoids (n<=4)	88±20%	48±7%	40%	67%	
Triazoles (n<=5)	136±32%	36±32%	38±7%	77±52%	72±2%
Acetamides (n<=6)	140±44%	93±55%	46±21%	153±63%	

[a] n: number of analytes detected of a given compound class. Percentages are presented per compound class as means and standard deviations from individual compounds. Missing numbers indicate that the compounds were not detected.

With 38 target analyses, the established analytical method based on Chiaia-Hernandez et al. (2017) only includes 13 out of the 57 pesticides classified as such “with a particular risk potential” (Action

Plan Plant Protection Products, Appendix 9.1). From the goals of the AP PPP related to application rates, emissions, and soil quality, which require quantitative information on corresponding reductions of these compounds in particular, it follows that they must be included in the list of target analytes.

3.3 Indicators to assess effects on soil quality

Switzerland has a long-standing interest to the quality of its soils. The Swiss Ordinance 814.12 from 1998 relating to impacts on the Soil (Verordnung über Belastungen des Bodens (VBBo); Ordonance sur les atteintes portées au sol (Osol)) requires soil fertility to be guaranteed in the long term (Art.1). According to Art. 2a, a soil is defined as fertile if the biologically active community, the soil structure, the composition and the thickness are typical for its location and if it has an undisturbed decomposition ability. We will use this definition for a soil of high quality and will use the term 'soil quality' instead of 'soil fertility', since soil fertility usually mainly considers the production function, putting only few emphasis on the state of the soil biocenosis. However, soil organisms, through their diversity and functions, are key players for maintaining soil quality. They can thus serve as bioindicators to assess effect of PPPs on the quality of the soil and must therefore be highly considerated.

At the national level, the working group "Soil Biology" (Vollzug Bodenbiologie (VBBio) / Biologie du sol – Applications (BioSA)) made up of stakeholders from the cantonal and federal authorities, already elaborated in 1999 a strategy regarding soil biology and soil protection (VBB-BSA, 1999). The report describes the possibilities of application of pedobiological parameters, especially for long-term observation and for the evaluation of soil quality in case of environmental damages. In a second report published in 2009, the "Soil Biology" working group aimed at giving recommendations on the use and interpretation of biological parameters ("indicators of soil quality", including microbial parameters, mycorrhiza and earthworms) for the assessment of soil quality. For microbial parameters, site specific reference values have been established for arable lands of the Swiss Plateau depending on soil physico-chemical parameters (Corg[3], pH, clay and humus content) (VBB-BSA, 2009). In 2012, the NABO started a soil biological monitoring (NABObio) for a selection of 30 sites (including 10 arable lands) to monitor soil quality in Switzerland. This monitoring mainly focuses on microbiological and biomolecular parameters such as microbial biomass, soil respiration, DNA content, species richness, and composition of the microbial population (Hug et al. 2018).

At the Cantonal level, biological indicators are also used to monitor soil quality. Canton Bern, for example, is using microbial parameters but also earthworms and mycorrhiza for the monitoring of soil quality at their observation sites (Kantonale Bodenbeobachtung KABO), while Canton Fribourg, Aargau or Grison are only using microbial parameters (i.e. C-min[4], biomass, basal respiration, metabolic quotient…). Arable lands are part of the observation sites of all these Cantons, with more than 100 sites for Canton Fribourg (around a dozen for the others).

These national and cantonal monitoring programs mainly compared the follow up of biological parameters over long time and between different types of land-use (arable land and grass land, sometimes forest and urban sites). Biological indicators were currently never employed in large-scale studies to monitor the potential effect of PPPs (i.e. in regard to residues, crop rotation or type of cultures) on soil organisms and soil quality.

At the international level, the European Food Safety Authority (EFSA) recently published an Opinion Paper addressing the state of the science on risk assessment of PPPs for in-soil organisms.

[3] Corg: Organic carbon in soil
[4] C-min: Mineralized carbon in soil

Recommendations are made regarding model species to be used at first tier. For higher tiers, the assessment of the community response of in-soil organisms exposed to PPPs is proposed (EFSA 2017). Biodiversity, nutrient cycling, food web support, and soil structure were listed as those soil ecosystem services potentially affected most by pesticides and encompass the majority of key organisms. Specific protection goals (SPG), ecosystem services and ecosystem functions are further discussed in chapter 5.2.3. The main biological indicators and parameters used to assess the effect of PPPs on soil and in-soil organisms are listed in appendix 7.3 .

3.4 Soil Reference Values

Soil Reference Values (SRV) or Soil Screening Values (SSV) are numerical values, referring to contaminant concentrations in soil. These values should protect terrestrial organisms and critical ecological functions from unacceptable effects caused by contamination (Fishwick 2004; American Petroleum Institute Biomonitoring Task Force 2003). The development of reference values is a step-wise approach. The first step is based on the collection of ecotoxicological responses and exposure relationship data from the literature for terrestrial organisms. In a second step, data are submitted to a quality control screening process so that only suitable data from studies meeting defined criteria (e.g. CRED: Criteria for reporting and evaluating ecotoxicity data; Moermond et al. 2016) are included in the final database. In the last steps, effect-based criteria are estimated, and final screening values are determined. In most cases, ecotoxicity data are normalized to consider soil heterogeneity and confounding factors such as soil pH or organic matter content (Fishwick 2004; EC TGD 2002). Approaches for determining SRV are already well established and are proposed by some regulatory authorities. Examples are the European Commission (European Commission Technical Guidance Document "EC TGD" on risk assessment), The Netherlands (Guidance Document on deriving Environmental Risk Limits (Vlaardingen & Verbruggen 2007)), United Kingdom (Soil screening values for use in UK ecological risk assessment (Fishwick 2004)), Canada (Recommended Canadian Soil Quality Guidelines (CCME 1997)), and USA (Ecological Soil Screening Level Guidance (US EPA 2003)).

Currently, SRV have mainly been established for metals, some organic compounds like PAH, dioxines and furanes, chlorobenzenes and only very few persistent pesticides (e.g. dieldrin, DDT and HCH) in the above-mentioned countries, but also in Switzerland (OSol/VBBo 1998). No reference values are available for PPPs that are currently on the market. One of the major problems in developing SRV is the paucity of the soil ecotoxicological data available in comparison to the ones that can be obtained for the aquatic compartment. However, very recently Czech and Italian researchers gave a try for developing soil reference values for some PPPs in agricultural soils (Pivato et al. 2017; Vašíčková et al., 2018). In both cases, the EC TGD approach was used to derive SRV.

3.5 Workshop summaries

As part of our activities for developing this concept, we invited national and international experts and stakeholders to share their knowledge with us at two different workshops. The following paragraphs summarize the contents that we discussed during each workshop and the learnings we took from it.

3.5.1 First workshop

The first workshop took place in September 2018 in Bern, Switzerland and was joined by national experts.

3.5.1.1 Exposure part

NABO presented its screening and monitoring concept with regard to PPP in soil. In the following plenum discussion, the goal of monitoring PPP in soil was defined to protect soil fertility from unacceptable risk due to use of PPP use. It remains however to be determined which soil properties define good soil fertility and what needs to be protected.

Following the plenum discussion, we formed two smaller working groups to encourage a discussion on how to select the relevant substances and sites to be monitored. With regard to selecting substances, the experts named the following aspects as relevant: Eco- and toxicological relevance including their bioavailability, amount and frequency of usage, persistence in the soil, and analytical determinability. Thereby, the group advised us to focus on substances given in Annex 9.1 of AP PPP and limit ourselves to substances that hold a registration for use in Switzerland. Furthermore, the group advised us to update our list regularly to mirror the latest developments in active registrations. Nevertheless, the experts cautioned us to implement changes with delay to account for grace periods and general inertia of the system.

With regard to selecting sites, the question was whether to focus on quantity or quality of sites. One group preferred a strategy of aiming for the largest number of sites and vastly extending the current NABO site collection with the help of other monitoring networks such as cantonal soil monitoring networks (KABO) or the Swiss Agri-Environmental Data Network (ZA-AUI, "Zentralen Auswertung Agrarumwelt-indikatoren"). Another group of experts remarked that without knowing the PPP application history it will be difficult to interpret the measured soil concentrations and we should thus focus on those sites where we can obtain management data. However, it was without question that soils of PPP use intensive land uses such as vineyards and orchards need to be studied more intensively and that we need to consider regional aspects in our monitoring design.

With regard to temporal variability, we could generally agree that for a multi-year long-term monitoring, minimizing the short-term variability by sampling in between vegetation periods is a sensible approach. However, this approach neglects short-term variability and concentration peaks, which are both relevant for the interpretation of ecotoxicological affects. Consequently, we should take into consideration to sample in higher temporal frequency and to include the vegetation period.

3.5.1.2 Ecotoxicology part

In order to start the concept development of bioindicators for soil quality in Switzerland, two approaches were presented during a stakeholder workshop with national experts held in September 2018 in Bern, Switzerland. The first approach is the substance-based approach, which is linked to the prospective risk assessment. This approach relies on well-established laboratory physicochemical analyses of single chemical concentrations and on institutionally standardized ecotoxicological single species tests run in the laboratory. Thus, in the substance-based approach the risk of the single compound is independently characterized. This approach does not take into account the bioavailability of the assessed chemicals and implements a modeling approach to predict the combined effects of a mixture of pollutants. Furthermore, substance degradation is only determined in three standard soil types and does therefore not reflect the realistic scenario of substance degradation and effects on soil organisms in the field.

The second approach is the matrix-based approach, which is linked to the retrospective risk assessment. This approach may overcome the drawbacks of the substance-based approach, as it assesses the effects of all chemical substances currently present within the real matrix. Furthermore, if biotests are conducted in the field, interactions between soil organisms are also allowed and considered. However, if a risk for soil is identified, it is more complicated to refer to the respective substance/substances that impose risk to soil organisms.

During the first workshop, the majority of participants agreed that for the risk assessment in Switzerland, both approaches should be combined. It was also agreed on that the effects of PPP should be considered for microorganisms, soil invertebrates, and plants. Also, effects should primarily be considered in-field, but off-field areas like field margins or ecological compensation areas should be considered as well, e.g. by deriving separate screening values for in-field and for off-field areas.

3.5.2 Second workshop

The second workshop for the development of a monitoring concept took place in November 2018 in Zurich, Switzerland with national and international experts and stakeholders.

3.5.2.1 Exposure part

During the exposure part, experts from Wageningen University, The Netherlands and Recetox, Czech Republic presented their research on PPP monitoring in soils. Both emphasized the usefulness of farmers' management and application records when interpreting the measured PPP residue concentrations. As for the selection of compounds, analytical limitations are a determining factor especially for transformation products, for which less experience exists. Transformation products should be in the focus when sampling in the beginning of the year, as they are expected to be present in the soils rather than the parent substances. Furthermore, when presenting risk analysis, both experts advised us to mention which compounds we are not measuring and explain why not.

We then presented our own concept for monitoring PPP in Swiss arable soils and discussed it with the expert panel. As a result, we made the following amendments to our concept. To address the short-term variability and peak concentrations in addition to the long-term variability, we include a work package where we will sample a small number of sites in monthly increments during a period of two years. Furthermore, we discussed whether the current NABO sampling design with a 10x10 m plot representing the entire field is suitable to mirror the onsite variability. As PPP are normaly applied in a uniform amount per area, we consider this method adequate to represent the current application practice. However, for the future we need to consider that the advance of precision farming will add variability in the amount applied by area. We considered thus to review the current sampling design in the course of this project. Furthermore, we profited from intelligence on local predominance of certain crops on which we base the number of sites necessary to represent vegetable growing regions. Advice on the impact of animal production, cropping intensity and soil tillage on soil quality and PPP use leads us to include these factors in our criteria for selecting sites to extend and review the NABO site collection.

3.5.2.2 Ecotoxicology part

With regard to effect assessment, the focus of the second workshop was on the matrix-based approach and on suitable bioindicators to assess effects on soil quality. Soil functions as well as biodiversity need protection. However, detailed protection goals have not been defined yet for soil. Furthermore, standardized monitoring and assessments methods for field studies are mainly lacking. Microorganisms are a potential suitable bioindicator. They provide a wide variety of soil ecosystem functions. The nitrogen cycle and the arbuscular mycorrhizal fungi test were presented as promising new methods for estimating PPP impact on soil microbial communities. Regarding biodiversity, according to EFSA (EFSA, 2017), a minimum of four of the eight organism groups representing the soft- and hard-bodied meso- and macrofauna are recommended for a risk assessment in temperate regions. Genetical methods for species taxonomy will likely complement classical morphological taxonomy in the future, but methods still need further development as well. A tiered approach, like the triad approach for contaminated soils, seems suitable for the assessment of PPP effects on soil quality as well.

4 Research hypothesis and objectives

The overall research hypothesis of this long-term monitoring program is that,

- Following the use of PPP according to good agricultural practice (GAP), residues of some PPP and their transformation products do remain in the soil over extended periods and thus may have long-term effects on the soil quality.
- Different types of intensive agronomic land-use (cropland, viticulture, orchards, etc.) will result in different typical combinations and exposure levels of PPP residues.
- For a given soil use, different soil types would also result in different PPP residue patterns.
- Long-term exposure to PPP residues in soil will affect some of the functions the soil performs and/or the structure of soil organisms' community and therefore by extrapolation, soil quality.
- The combination of PPP residues present in soil will result in mixture effects on soil organisms (concentration additivity).

The objective of the monitoring program and its preliminary screening campaigns is

- To give knowledge-based feedback to risk managers about long-term soil exposure concentrations and their persistence following the use of PPP under real-world conditions.
- To give information about typical combinations of PPP residues present in the soil.
- To better assess long-term effects of PPP residues on soil organisms and soil quality from an *a posteriori* risk assessment perspective.
- To better understand the link between soil organisms, functions and ecosystem services.
- To give suggestions what measures could lead to a 50% reduction of risk to soil quality

With this work, we aim to answer the following questions:

- What PPP residues are present in Swiss soils, in which concentration levels are they present and how persistent are they?
- Are there typical combinations of PPP residues for specific types of land-use and soil management and what are they?
- Which indicators could be used to measure the effect of acute and long-term exposure to PPP residues on soil quality?
- Are there non-reversible effects on soil quality from acute and long-term exposure to PPP residues?
- Is the current, prospective laboratory-based, risk assessment of the registration process conservative enough to protect the soil quality in Switzerland in the acute and in the long run?
- Is it feasible to develop and use reference values for PPP residues in Swiss arable land soils?
- Which amount/types/methods of PPP application can we accept while reducing the risk on soil organisms by 50%?

5 Work program

5.1 Scope

Plant protection products (PPP) describe products containing chemical or biological a.i., whose purpose is primarily to protect agricultural crops against plant diseases (fungicides), insect pests (insecticides) and weeds (herbicides). In addition, users apply PPP against mites (acaricides), roundworms (nematicides), nudibranchs (molluscicides) or bacteria (bactericides). The present project focuses on residues of chemical-synthetic PPP used in agriculture. PPP residues include a.i. of PPP and their major transformation products. PPP are mainly used in agriculture, but they are also used in forestry, private gardens, parks and sports fields. With respect to land-use, we focus on intensive agricultural land-use in Switzerland and apart from negative controls needed for experimental design and statistical reasons exclude forestry, urban, industrial, permanent grassland, parks, as well as pasture and private gardens.

5.2 Research design and methods

Not every research question related to the use of PPP necessarily warrants the significant effort connected to a long-term monitoring. The NABO has thus developed a general workflow (Figure 2) to decide whether a topic will be included into their long-term monitoring routine.

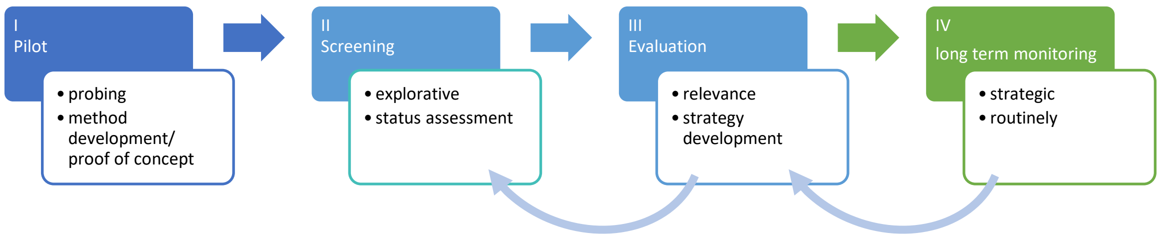

FIGURE 2 PATHWAY TO LONG-TERM MONITORING PROGRAM

The individual phases along this workflow are:

I. Every new topic will go through a **pilot** phase. This is the first step we use to explore a new topic, develop new methods and demonstrate their feasibility.

II. In the **screening** phase, the goal is to gain a broader more in-depth overview. For this purpose, we will commonly aim for a large number of samples, a broad range of areas and a wide selection of substances.

III. We will then scrutinize the thus generated information based on a set of decision criteria on whether the topic is relevant enough and shows sufficient temporal dynamics to include it into the long-term monitoring program. Furthermore, during this phase we will develop the strategy for the long-term monitoring. In the **evaluation**, data gaps may become apparent, which may then be addressed with another screening. It may thus take several iterations until a confident decision is possible, whether to include a topic to the long-term monitoring program.

IV. When a topic is deemed worthy for a routine **long-term monitoring**, it will be regularly studied in a systematic and strategic fashion and regular reports will be issued to inform about its development. As every new sampling campaign within the long-term monitoring routine brings new information, this leads to regularly re-evaluating the monitoring concept of any topic.

In outlining the steps necessary to build up a long-term monitoring of PPP residues in the soil, this draft concept focuses on describing work packages belonging to Phases II Screening and III Evaluation. The following chapters will describe criteria and concrete steps we will take to select relevant compounds and to set up the sampling strategy. The research design outlined below is the result of comprehensive literature research, preliminary studies and expert consultation during two workshops which have been summarized in Chapter 3.5.

5.2.1 Selection of relevant compounds

From the list of currently registered PPP available for use in Switzerland, we will select relevant compounds (active ingredients and their major transformation products) for observation in the long-term monitoring program. Taking into account substances listed in Annex 9.1 of AP PPP, we will select them based on the following criteria: eco- and toxicological relevance, persistence in the soil, bioavailability[5], amount and frequency of usage, analytical determinability and stakeholder interest (Figure 3). Thereby we will aim for a balance between effect and exposure criteria. Regular updating of the list of compounds will help us to mirror current developments (new a.i., non-renewal, change in sales rankings, etc.) at the time of sampling and make the most efficient use of our resources. When we exclude compounds from the monitoring list, we will do so with a lag phase to account for memory effects in the system.

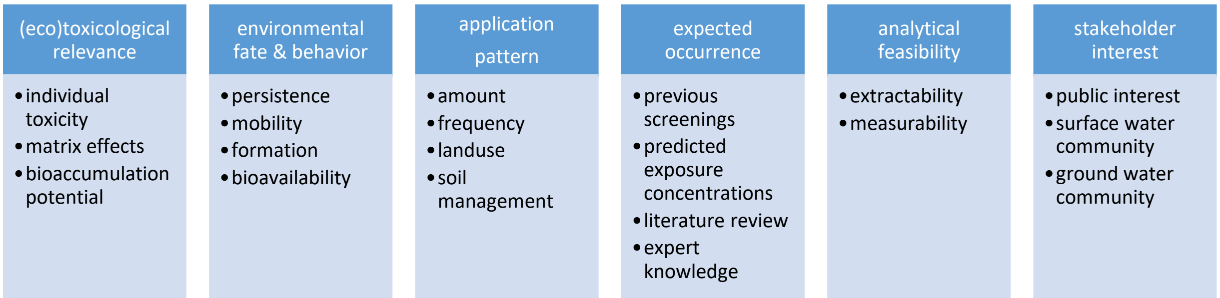

FIGURE 3 OVERVIEW OF CRITERIA TO SELECT ACTIVE INGREDIENTS AND THEIR TRANSFORMATION PRODUCTS FOR MONITORING

5.2.1.1 Ecotoxicological relevance

Additionally, we will consider (eco)toxicological aspects such as known toxicity to soil organisms or substances that needed a refined risk assessment during the registration process. Bioaccumulation potential based on its bioconcentration factor (i.e. ratio of the concentration of a substance in the organism compared to the concentration in the matrix surrounding the organism) of the respective substances shall also be taken into account.

5.2.1.2 Environmental fate & behavior

For the long-term monitoring, we plan to take those compounds into account that we expect will show slow degradation and low mobility. With regard to transformation products, in addition to the above-mentioned criteria, we also consider their formation rate.

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[5] In the course of the Screening and Evaluation phase an analytical method to quantify the PPP residues of relevant substances will be developed. With regard to bioavailability the extraction method represents a conservative quantification of the potentially bioavailable fraction. Depending on the author, some of the extracted fraction can be defined either as slowly desorbable (Kästner et al. (2018), Reichenberg & Mayer (2006)) or as non-extractable fractions (NER)(ECETOC, 2013). Consequently, the current method will allow us to estimate the risk of exposure conservatively. Research on defining in situ bioavailability of NER for different organisms is out of scope.

5.2.1.3 Application pattern

With regard to the application from the soil management data, we will look at how frequently and in which quantities the compounds are typically applied. Thereby, we will consider different types of agricultural land uses, including the spatially predominant crop farming and the spatially less dominant but equally relevant horticulture. We will not take into account extensive land-use forms such as grassland, alpine pasture and forestry; we will consider neither urban areas, nor private gardens. Furthermore, we will consider different kind of soil tillage methods.

5.2.1.4 Expected Occurrence

From previous and currently running screenings, in combination with predicted environmental concentrations (PEC) from exposure modelling based on real application data we will get a better understanding of which compounds are present in the soil and at which levels. A thorough literature review will help us to evaluate the plausibility of our findings. Furthermore, we are grateful to be able to receive continuous guidance of our expert panel (Begleitgruppe) during the selection process.

5.2.1.5 Analytical feasibility

Furthermore, we will look at the analytical feasibility under consideration of cost benefit aspects. Some compounds will not be extractable with the current, already established multiresidue method (see above). We will place additional scrutiny on compounds that can only be quantified with a single substance method to evaluate whether the additional effort is justifiable in in light of its overall environmental risk.

5.2.1.6 Stakeholder interest

Finally yet importantly, we will take specific interests of stakeholders into consideration. For example, Glyphosate is the most used a.i. based on tonnage and consequently there is great public and political interest on its risk to humans and the environment. Another example are substances which may not be of highest priority from a soil risk perspective but where soil measurements can help stakeholders from succeeding environmental compartments such as ground and surface water to interpret their findings. Therefore, we will carefully balance stakeholder interests with the above outlined selection criteria.

5.2.2 Sampling strategy

5.2.2.1 Sampling strategy on-site

As discussed during the first Workshop, indicators of soil quality as well as the setting up of soil reference values will mainly be performed “in-field”. For selected cases, we are also considering field margins and ecological compensation areas (which might be used as references for example).

At field scale, horizontal spatial variability in soils is often equally variable on a scale of meters as on the entire field scale, and can thus be addressed with mixed bulk samples from a representative plot of 10x10 m. On a vertical scale, PPP residues show a gradient with highest concentrations in the topsoil. In tillaged plots, this gradient will be homogenized in the plowing layer (ca. 0-20 cm). Here we will take samples in 0-20 cm. On permanent culture, the soil is usually not tilled and thus the concentration gradient is intact. The highest concentrations are expected to occur in the topmost centimeters, which is also the area with the highest population of soil organisms. A mixed soil sample from 0-20 cm depth for example, will underestimate the concentrations and underestimate the risk for soil organisms. To address this fact, on permanent cultures and no tillage cropping we will take two composite samples, 0-5 cm and 5-20 cm depth[6], respectively.

5.2.2.2 Sampling time and frequency

Both soil input and soil dissipation of PPP residues are highly variable in time. The initiators of the AP PPP are especially interested in gaining knowledge on whether the current risk management protocol is able to prevent unacceptable long-term effects on the soil quality (Bundesrat, 2017). Consequently, we are most interested in the long-term exposure and less interested in short-term peaks of concentrations. Nevertheless, peak and short-term exposure concentrations can affect the soil organisms' capability to accept long-term exposure without permanent harm. For reasons of financial feasibility, short term and peak exposure will, after an initial high-resolution screening of measured exposure concentrations with monthly sampling (WP Temporal variability), in general be approximated by predicted exposure concentrations.

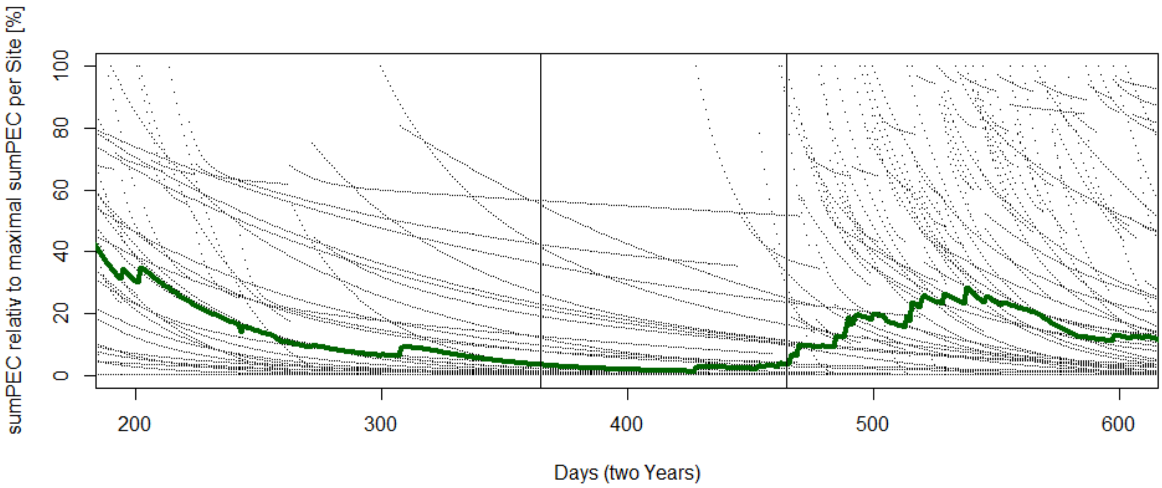

FIGURE 4: RELATIVE SUM OF PREDICTED PPP CONCENTRATIONS (TIER 1) OVER TWO YEARS (GREY LINES). 100% IS SET AS MAXIMAL SUM OF PPP PER SITES IRRESPECTIVE OF LAND-USE OVER TWO YEARS. THE GREEN LINE REPRESENTS THE MEDIAN OVER ALL OBSERVATIONS. VERTICAL SEGMENTATION LINES ARE SET AT 365 AND 465 DAYS.

Preliminary Tier 1 modeling results show that the lowest and least variable soil concentrations within a year likely occur from December to March (Figure 4, days 365-465). In Switzerland, this time window is mostly outside of the vegetation period and marks the period in which the farmer is least likely to apply PPP.

5.2.2.3 Site selection

Although the NABO selected their sites in the mid 1980's with the premise to give a good representation of soil conditions in Switzerland, they are not representative with regard to the use of PPP (Gubler et al. 2015). For example, comparison of PPP use on NABO sites with data from other

[6] Adopting a strategy of sampling two depths (0-5 cm, 5-20 cm) for all sites would lead to additional costs of approximately 200-300 kCHF without generating additional value, since tillage in autumn will have mixed and diluted the concentration gradient.

studies (de Baan et al. 2015), shows that farmers on NABO sites on average use PPP less frequently than the average ÖLN[7] farmer.

Furthermore, the current selection of NABO sites underrepresents sites with permanent cultures and vegetable growing. Out of 47 sites currently included in the research done on PPP during the Pilot and the 1st Screening, the majority of samples stem from crop land, whereas only few soils from orchards and vineyards have been analyzed (Table 2). Even when spatially representative, the sample sizes are too small to allow any generalizations on PPP use and the following PPP residues.

TABLE 2 NUMBER OF SITES PER LAND-USE CLASS IN PILOT AND SCREENING

Land Use	Pilot	Screening 1	Duplicates	Σ	Percent of total	Percent area of total agriculture land in CH[8]
Crop land	7	27	(6)	28	60%	38%
Vegetable growing	1	1	(1)	1	2%	1%
Permanent grassland	0	8	0	8	17%	58%
Orchards	3	3	(3)	3	6%	<1%
Nature reserve	0	1	0	1	2%	-
Urban park	0	2	0	2	4%	-
Vineyard	3	4	(3)	4	9%	1%
total	17	46	(13)	47		

Therefore, our aim is to extent the selection to have a sample representing the most PPP intensive land-use forms, orchards, vineyards and vegetable growing, with a sample large enough to reach statistical significance. This, while representing the spatially most relevant land-use forms in a large enough sample to credit their inherent variability. Furthermore, we attempt to include a small number of sites with no pesticide application (negative controls) to establish knowledge on diffuse contamination concentrations from ubiquitous introduction of PPP residues to the soil without intentional PPP application and on what would be the best possible condition with respect to soil quality.

In addition to representativeness of land use, crop rotation and PPP application intensity, we will furthermore pay attention to physical, chemical, and biological properties of the soils (Table 2). When selecting the monitoring sites, we will give preference to sites, which are already monitored closely and are best characterized (i.e. have the most soil data and PPP management data readily available).

[7] ÖLN "Ökologischer Leistungsnachweis": Proof of Ecological Performance; Financial instrument to promote good agricultural practice with increased standards on ecological sustainability.
[8] BfS (2018): Arealstatistik 2017

TABLE 3 ASPECTS TAKEN INTO CONSIDERATION FOR SITE SELECTION

Landuse	Soil properties	Climate conditions	Expert knowledge	Feasibility

• including:
  • intensive agricultural
• excluding
  • forestry
  • urban
  • industrial
  • private gardens
  • extensive agricultural
  • alpine
  • pasture
	• physical
	  • sand and clay content
	  • predisposition for preferential flow
	• chemical
	  • org. C.
	  • pH
	  • cation exchange capacity
	• biological
	  • soil respiration
	  • microbial diversity
		• regional differences affecting pest pressure and soils ability for degradation
		  • temperature
		  • precipitation
		  • solar radiation
			• PPP application
			• existing information on PPP residues in soil
				• landowners willingness to
				  • allow long-term monitoring
				  • supply PPP application records
				• synergies with other progams

In the attempt to create synergies with the existing structures while extending the site selection, we plan to reach out to PPP application monitoring networks (e.g. Swiss Agri-Environmental Data Network ZA AUI), cantonal soil monitoring networks, soil surveys, water monitoring networks and other research programs (e.g. “Ressourcenprojekte”).

Finally yet importantly, we are highly dependent on the landowners’ cooperation. We prefer sites on which the landowner supports a long-term monitoring and is willing to supply her management and PPP application records.

5.2.3 Indicators to assess effects on soil quality

Suitable indicators to assess effects of PPP residues on soil quality will have to be identified or developed. Currently, the list of existing biological indicators to assess effects of chemicals on soil organisms (as international standards or not) is huge. They are available for different levels of the soil food web (from primary producers to top predators), for the functions they perform (mainly for microorganisms), as single species or for the structure of the community. The main bioindicators available and the parameters measured (endpoints) to evaluate the effect of PPPs on in-soil organisms are given in the table in appendix 7.3. The EFSA 2017 report on risk assessment of PPPs for in-soil organisms is also giving a detailed overview on the subject. According to the list of available bioindicators and to the last conclusions of the EFSA (EFSA 2017), but also regarding the outcomes of the 2nd workshop, the current major developments and needs are focused on microorganisms and the soil microbial community, but also on monitoring effects of substances in the field at the community level for soil organisms in general.

However, despite almost several decades of development in this field, it is still difficult to make the link between responses given by the bioindicators (measured endpoints) and the exact repercussions it has on the related soil functions, soil quality and ecosystem services. Evaluating an effect at contaminated sites might also sometimes be difficult as data regarding baseline conditions are most of the time currently not available. Thus, the determination of normal operating ranges (NOR) is another challenge for the development of suitable bioindicators and the risk assessment.

Regarding assessment of effects of PPP on soil quality and the selection or development of indicators, the first step necessary for the development of a concept for effect monitoring is to define the protection goals regarding soil quality more precisely (when is a soil considered to be fertile/of high quality) as well as prioritizing the soil functions that must be protected. This is essential for the selection or development of suitable and pertinent indicators for this purpose.

The first step in the definition of specific protection goals (SPGs) is the identification of functions or ecosystem services that are considered important and are provided by agricultural ecosystems. Seven ecosystem services were identified by EFSA 2017, as being driven by in-soil organisms in the agricultural landscape. These services are:

Ecosystem services driven by in-soil organisms	**Explanation**
• Genetic resources, biodiversity	In-soil organisms are extremely diverse and contribute highly to the biodiversity of agricultural landscapes.
• Education and inspiration, aesthetic values and cultural diversity	In-soil organisms support with their activity the formation of typical structures in agricultural landscapes, delivering aesthetic values, cultural heritage and sense of place. The aesthetic value of soils is widely acknowledged.
• Nutrient cycling	The cycling of nutrients in soils is the basis for terrestrial life. Dead organic matter from above- and below-ground is degraded by detritivores and finally mineralised by microorganisms. Mineralised nutrients can be then taken up by plants.
• Regulation of pest populations and of disease outbreaks	In-soil organisms are valuable antagonists of soil-borne pests affecting crop-plant species and have the potential to control the outbreaks of plant diseases.
• Soil remediation, natural attenuation	In-soil organisms degrade a variety of compounds in soils and contribute to the natural attenuation of xenobiotic soil pollution, including pesticides and their residues.
• Soil-structure formation, water retention and regulation	In-soil organisms are important drivers of soil-structure formation and maintenance. The activity of soil organisms modulates aggregate formation, alleviate soil compaction and regulate soil water-holding capacity.
• Food provision, food-web support	In-soil organisms are part of the below-ground food web and are the link to above-ground consumers. They are providers of secondary production and support biodiversity at a higher trophic level.

The Food and Agricultural Organization of the United Nations (FAO) suggested ten essential functions performed by soil organisms (Soil macrofauna field manual, 2008):

Functions	Organisms involved
• Maintenance of soil structure	Bioturbating invertebrates and plant roots, mycorrhizae and some other microorganisms
• Regulation of soil hydrological processes	Most bioturbating invertebrates and plant roots
• Gas exchange and carbon sequestration (accumulation in soil)	Mostly microorganisms and plant roots, some C protected in large compact biogenic invertebrate aggregates
• Soil detoxification	Mostly microorganisms
• Nutrient cycling	Mostly microorganisms and plant roots, some soil and litter feeding invertebrates
• Decomposition of organic matter	Various saprophytic and litter-feeding invertebrates (detritivores), fungi, bacteria, actinomycetes and other microorganisms
• Suppression of pests, parasites and diseases	Plants, mycorrhizae and other fungi, nematodes, bacteria and various other microorganisms, Collembola, earthworms, and various predators
• Sources of food and medicines	Plant roots, various insects (crickets, beetle larvae, ants, termites), earthworms, vertebrates, microorganisms and their by-products
• Symbiotic and asymbiotic relationships with plants and their roots	Rhizobia, mycorrhizae, actinomycetes, diazotrophic bacteria and various other rhizosphere microorganisms, and ants
• Plant growth control (positive and negative)	Direct effects: plant roots, rhizobia, mycorrhizae, actinomycetes, pathogens, phytoparasitic nematodes, rhizophagous insects, plant growth promoting rhizosphere microorganisms, biocontrol agents

The second step in the definition of SPGs is the characterisation of the main drivers behind the ecosystem services deemed to be important in agricultural landscape. Key drivers are defined as the structural and functional components of ecosystems necessary to deliver a given ecosystem service at the level required by service beneficiaries (adapted from Luck et al., 2003; Vanderwalle et al., 2008). The third step is the determination of the drivers' ecological entity to be considered with respect to the ecosystem service assessed. The PPR Panel (EFSA PPR Panel, 2010a) suggested to differentiate between the ecological entities 'individual', '(meta)population', 'functional group' and 'ecosystem'. In the case of SPGs for in-soil organisms, the ecological entities relevant to deliver different ecosystem services are either the populations of species or the functional group. The fourth step is the determination of the drivers' attribute to be measured in the assessment. Changes in behaviour, on survival and growth, in abundance/biomass, in a process rate or in biodiversity are suggested by the PPR Panel (EFSA PPR Panel, 2010a) as possible measurements to be made for the different drivers considered. In the case of in-soil organisms, and according to the ecological entities considered in the previous step, the most reasonable attribute to measure will likely be abundance and/or biomass. The fifth step is the determination of the magnitude of effect on the drivers that could be tolerated regarding the impact on the respective ecosystem service without affecting the general protection goal. The sixth step is the determination of the temporal scale to be considered together with the magnitude of tolerable effects. The seventh step is the determination of the spatial scale.

As this stepwise approach is a long-term process and potentially requires more results and research, the use of bioindicators currently employed in monitoring programs in Switzerland should be considered in parallel for the development of the concept of effect monitoring. Indeed, microbial parameters as well as earthworm communities are biological indicators currently used in Switzerland and are in line with the recommendations from the 2nd workshop and EFSA report. Moreover, for some of the microbial indicators employed, site-specific reference values are already available for the Swiss Plateau. Their use in the context of the monitoring of PPP effects on soil quality for arable land should be further investigated.

5.2.4 Soil Reference Values

Based on the substance list defined by the NABO, the first step will be to assess the feasibility for a sub-selection of substances of developing pertinent soil reference values (SRV) based on the amount of soil ecotox data available and following a stepwise approach.

Indeed, when regarding the 40 substances from the NABO's first screening list, soil ecotox data available for soil dwelling organism from databases such as the "Ecotox US-EPA database" is generally less than 10% of the total terrestrial ecotox data available (including mammals, birds, plants and insects.) If the amount and quality (e.g. Criteria for Reporting and Evaluating ecotoxicity Data CRED) of the data gathered during the pilot phase is considered as acceptable, the development of soil screening values will then be extended to the whole list of chosen substances.

Moreover, an approach for risk assessment of PPP mixture will have to be considered and developed where feasible, as several pesticides might be present at the same time in the soil matrix.

5.3 Work packages (WP) and Milestones (M)

The following table outlines the anticipated timeframe and milestones (including deliverables) for the project (Table 4).

TABLE 4 TIMEFRAME AND MILESTONES OF THE PROJECT

Activities	Lead	2019			2020			2021			2022			2023			2024			2025			2026			2027		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Exposure monitoring		**Phase II and III Screening and Evaluation**																	**Phase IV Routine Monitoring**									
Deliverables	**NABO**			D			D			D			D			D		D										
5.3.1 Core WP	**NABO**	M1	M2														M8	M9										
5.3.1.1 Data evaluation, modelling etc.	*NABO*						M4					M7																
5.3.1.2 Analytical Method development and validation	*Environ. Analytics, Agroscope*									M6																		
5.3.1.3 Routine exposure monitoring on NABO sites >2021	*NABO*										M3																	
5.3.1.4 Knowledge transfer	*NABO*		▪○	▪◊		▪○	▪		▪○	▪◊		▪○	▪		▪○	▪		▪○	▪◊		▪○	▪		▪○	▪		▪○	▪◊
5.3.1.5 Routine exposure monitoring on AP PPP sites >2024	*NABO*																											
5.3.2 Thematic WP[9]	**NABO**																											
5.3.2.2 WP Temporal variability	*NABO*			M3							M5		M7															
5.3.2.3 WP Cropland	*NABO*										M3			M5		M7												
5.3.2.4 WP Orchards and vineyards	*NABO*						M3						M5		M7													
5.3.2.5 WP Vegetable	*NABO*										M3			M5		M7												
Effect monitoring		**Phase I Pilot**													**Phase II and III Screening and Evaluation**													
WP Risk-based reference values	ETX									M 10												M 11						M 15
WP Indicators	ETX												M 12									M 13						M 14 M 15

WP = work package, M1-M15 = milestones, D: annual deliverables, ETX: Swiss Centre for Applied Ecotoxicology (Centre Ecotox Eawag-EPFL) and EnviBioSoil, dark blue: Phase I Pilot, light blue: Phase II and III Screening and Evaluation , green: routine monitoring , light grey: preparation or maintenance phases, yellow: final risk assessment testing phase at NABO sites, ▪ project team meeting, ◊ stakeholder meeting, ○ attending AP PSM meeting

[9] Two workpackages, 5.3.3.1 Sampling strategy on site and 5.3.3.6 Soil tillage, where put on-hold until further notice.

The following milestones with deliverables will be passed throughout the project

- M 1: Final concept outlining the steps necessary for establishing a long-term monitoring available
- M 2: List of relevant PPP residues including their a.i. and their major transformation products to be included in the routine monitoring is available
- M 3: Selection of sites finalized
- M 4: Multiresidue modelling according to FLUX management data concluded
- M 5: Sampling and chemical analysis concluded and quality controlled/assured
- M 6: Analytical method for quantification of relevant PPP residues in soil including standard operation procedure is available for subsequent screening and evaluation phases, as well as routine measurement
- M 7: Data evaluation and interpretation concluded and reported
- M 8: Site selection finalized and confirmed
- M 9: Final concept for exposure monitoring confirmed
- M 10: Risk-based reference values available for a sub-selection of PPP residues
- M 11: Risk-based reference values available
- M 12: Selection of indicators to be tested in the field available
- M 13: Evaluation of selected indicators accomplished
- M 14: Indicators available
- M 15: Soil risk assessment approach finalized

The following yearly deliverables D within the scope of exposure monitoring have been agreed on:

- D 2019: Report containing:
    - Final list of substances to be analyzed
    - Site selection temporal variability
    - Final list of NABO sites
- D 2020: Report containing
    - Site selection WP Orchards
    - Final results of multiresidue modelling according to FLUX management data
- D 2021: Report containing
    - Interim results of WP temporal variability
    - Final method for chemical analysis
- D 2022: Report containing
    - Site selection WP vegetables
    - Results of long-term variability analysis
- D 2023: Report containing
    - Site selection WP cropland
    - Final results WP orchards
    - Final results WP temporal variability
- D 2024: Final report Phase II&III
    - List of prospective sites outside NABO
    - Final results WP Cropland
    - Final results WP vegetables
    - Final monitoring concept

- D2026-2027: annual reporting on PPP concentration in soils

5.3.1 Core Work Package

Summary Core Work Package

- Data evaluation and fate modelling according to management data
- Development of analytical method covering most relevant substances and their transformation products
- Routine exposure monitoring of sites
- Knowledge transfer

The minimum effort necessary to reach an understanding on the exposure level of PPP residues in soils and assess their persistence under actual field conditions is described in the following paragraphs.

5.3.1.1 Evaluating, modelling and assessing existing information

The AP PPP sets the goal that until 2020 residues of relevant substances and their transformation products in soils are known and that they will then be reassessed on a regular basis. As minimum strategy, the NABO will continue the regular sampling program on NABO sites. We are excluding those sites on which we find unrepresentative low PPP applications and which are exchangeable duplicates in their characteristics with respect to land management, soil properties and climate conditions. Without context, measured PPP residues are meaningless. In order to be able to understand which level of intensity the current NABO sites represent with regard to the PPP application, we need to conduct a thorough comparison of the application patterns with application patterns on other sites representative for Switzerland. Furthermore, we need to conduct a comparison of predicted and measured exposure concentrations in the soil, so that we can give feedback to the registration authority on the protectiveness of the current risk assessment procedure. The EU guidance for the assessment on PECsoil (predicted exposure concentration in the soil) has recently changed, now offering a numerical model in addition to the analytical model to estimate PECsoil (EFSA, 2017a). Both need to be evaluated regarding their protectiveness for conditions in Switzerland. Furthermore, to increase modelling efficiency and create results that allow us to generalize, we will build multi PPP modelling scenarios representing conditions in Switzerland. Similar to FOCUS scenarios (Tiktak et al. 2013), our aim is to build conservative realistic worst-case scenarios with regard to the soils vulnerability, weather conditions and application patterns. Those scenarios will include typical agricultural land types and practices, spatial and temporal variability of crops, and representative application patterns.

5.3.1.2 Analytical Method development and verification

In addition to the regular physicochemical characterization of the samples, we will need to extract and analyze PPP residues and their major metabolites. Extraction and detection of PPP residues will initially be conducted using the established analytical method based on Chiaia-Hernandez et al. (2017). With 38 target analytes, this method currently only includes 13 out of the 57 pesticides classified as such “with a particular risk potential” (AP PPP, Appendix 9.1). Based the goals of the AP PPP related to application rates, emissions, and soil quality, which require quantitative information on corresponding reductions of these compounds in particular, it follows that new substances must be included in the list of target analytes. Therefore, new analytical methods need to be developed. A discussion on the details of the methodology for chemical analysis can be found in section 3.2.

To have meaningful impact for the authorities to enforce legislation and to be able to make use of internationally available research, sampling, detection and evaluation methods should be internationally harmonized and standardized. As an initial step to support the harmonization of analytical methods, a satellite event on multiresidue analysis will be held at the International Conference on Chemistry and the Environment (ICCE) 2019. During the monitoring preparation phase as well as in during the routine long-term monitoring, meetings with the international community shall be attended regularly to foster interlaboratory comparisons, including e.g. the establishment of reference samples.

5.3.1.3 Routine exposure monitoring on NABO sites >2021

As soon as the method development for those components on the list of relevant PPP residues is concluded, soil samples from NABO sites taken following the established sampling schedule will be routinely analyzed for PPP residues. Furthermore, measured PPP residues will routinely be evaluated in context with their respective PPP application data and reported regularly.

5.3.1.4 Knowledge transfer

This work package describes the efforts we are making to share our findings with the various stakeholder and expert communities. This includes regular meetings among the project participants and with the project lead. Furthermore, next to maintaining our project sharepoint, we will organize regular meetings to keep the stakeholders informed. Moreover, in addition to the annual reporting to the project management, we will present our results on international conferences.

5.3.1.5 Routine exposure monitoring AP PPP sites >2024

This tasks describes the added workload during the routine long-term monitoring on sites selected as a result of the below described thematic work packages in the screening and evaluation phase (AP PPP sites). Added workload includes the sampling of soil, chemical analysis, data evaluation of measured exposure concentrations, as well as evaluating PPP application records.

5.3.2 Thematic work packages

As outlined in the chapter on site selection above, the sites of the NABO collective are not representative for Switzerland with respect to the PPP application. Therefore, we advise to revise the current selection for the AP PPP. In the following, we describe work packages needed to reach a comprehensive understanding about the soil exposure concentrations of PPP residues, their spatiotemporal variability, factors influencing their retention, persistence and bioavailability as well their long-term effects on soils of respective uses in Switzerland, as requested in measure 6.3.3.7 in the Swiss AP PPP.

5.3.2.1 WP Sampling strategy on-site[10]

Summary WP Sampling strategy on-site • *Address challenges for sampling related with future innovations, such as precision farming*

For the purpose of exposure assessment we will collect soil samples as a bulk sample composed of 25 individual samples from a 10x10 m plot within a field, as advised in the "Manual for Sampling and Sample Pretreatment for Soil Pollutant Monitoring" (SAEFL, 2003). Currently, the vast majority of PPP are applied uniformly on a field on a gram per hectare application rate. We therefore expect little additional spatial variability from the application technique. On cropland, initial concentrations of PPP residues in the soil show little or no spatial correlation (Vischetti et al. 1997). On sites with

[10] *This package is set on hold until further notice*

permanent culture, care will be taken to include both in-row and between-row into the sampling plot. However, for preliminary status surveys as intended for permanent cultures and vegetables, a simplified sampling strategy might be implemented. On cropland and vegetable fields, samples will be taken in depth of 0-20 cm. On permanent cultures where no ploughing etc. takes place, we will take samples in two depths of 0-5 and 5-20 cm, respectively.

Monitoring sites selected for long-term observation will be characterized according to NABO procedures. Namely, the soil profile will be described based on soil cores and soil properties such as texture, pH and carbon content will be determined.

With the advance of precision farming, pesticide application techniques will become more spatially specific to take the spatial variable occurrences of pests, diseases and weeds into account. This will then challenge the above made assumptions on spatially variability of PPP residue concentrations in the soil. Furthermore, the high relief energy and steeper slope angles often found on permanent cultures, suggest at least some spatial correlation, if not in the initial concentrations then certainly after erosion. It is therefore advisable to review the current sampling strategy before the routine monitoring commences. We will address this problem by comparing sampling strategies on a small selection of land-use and regional representative sites.

5.3.2.2 WP Temporal Variability

Summary WP Temporal Variability

- Evaluate intra-annual variability of PPP residues based on measurements at few sites over two years and compare to fate models
- Evaluate inter-annual variability based on yearly sampling for selected NABO sites
- Define sampling period and interval for the long-term monitoring program

a.) Short term variability:
Not only the long-term exposure is relevant for the effect on soil quality but also time weighted average exposure and peak exposure, because a high exposure at one point in time can significantly affect the organisms' capability to endure long-term exposure to lower concentrations without suffering irreversible effects. We will address this problem with a combination of process based exposure modelling and high frequent (monthly) measurements on a small selection of representative sites over a period of two consecutive years.

b.) Long-term variability
Commonly, long-term terrestrial field dissipation studies do not exceed 2-3 years (OECD 2016) and modern pesticides are expected to have dissipated to more than 90% by the end of this time period (REGULATION (EC) No 1107/2009, Annex II, Chapter 3.7, EC, 2009). Consequently, from registration dossiers little information is available on long-term behavior of PPP residues beyond 2-3 years. Furthermore, registration dossiers typically address the environmental fate of a single compound. In a real world scenario however, soil organisms will be exposed to a combination of PPP residues. Since each compound has a different behavior in the soil, the concentration ratios in situ will differ significantly from the ratio at the time of application.
However, if we wish to answer the question whether the current application practice has lasting effects on the soil quality we need to gain information beyond the 2-3 year period and for a combination of compounds. The question is now to find a compromise between

available resources for sampling and chemical analysis and the necessary effort to measure the actual temporal variability. Because we expect the best cost-benefit ratio when following the NABOs sampling intervals, we are especially interested in whether the current quinquennial sampling frequency is sufficient to address our research questions.
In the course of the preparation period, we address this problem with a combination of analytical and process based (multiresidue) exposure modelling, literature study and measurements on samples annually taken from NABO-Bio sites. With the help of exposure modelling, we want to understand the temporal dynamics of PPP residues and their major transformation products in the soil. As modelling input, we will use existing application records and parameterize the models to the respective NABO-Bio sites.

5.3.2.3 WP Cropland

Summary WP cropland

- Extend collection of cropland sites to be representative for Switzerland

Cropland is by far the best represented land-use form in the NABO collective (Table 2). Still, the collection is not representative for Switzerland with respect to the PPP application. We should thus amend it to fit the purpose of monitoring PPP residues in soil. Based on the evaluation of PPP application data and the above outline selection criteria (mainly land management, soil properties and climate conditions) we will extent the current collection of NABO sites to reach the best possible representation of Swiss cropland. Additionally, we will aim to represent different subsidy schemes affecting the use of PPP, namely in groups of increasing restrictions with regard to the use of PPP from conventional to organic farming (e.g. conservative: free according to GAP, limited: limited use of pre-emergence pesticides under considerations of pest and disease pressure prediction tools, organic: no use of synthetic pesticides).

5.3.2.4 WP Orchards and Vineyards

Summary WP Orchards and Vineyards

- Status survey for orchards and vineyards
- Representative selection based on culture
- Define strategy for long-term monitoring of soils in orchards and vineyards

The number of PPP used and the frequency of interventions depend on the type of crop (Figure 1). On vineyards and orchards, the number of PPP and the frequency in which the PPP are applied is higher than on e.g. cropland (Figure 1). Furthermore, vineyards and orchards are permanent cultures whereas on cropland crop rotation is practiced. With regard to PPP use and residues in the soil, these are meaningfully different premises. On orchards and vineyards, the diseases and pests are usually similar from year to year. For resistance management reasons producers are advised to use a certain PPP only few times in direct succession. Yet, since the ripening fruits are exposed to diseases and pests for an extended period, multiple interventions are necessary to protect the crop which then need to be done with a variety of different PPP. On the contrary, crop rotation is the traditional form of management on cropland. As crops change, crop specific pests and diseases will change accordingly from year to year and so will the PPP. Furthermore, the number of interventions necessary within each cropping season will vary between each year. Additionally, soils of orchards and vineyards often have a litter layer, which may affect the concentrations of PPP residues in the soil. Moreover, orchards and vineyards are no-tillage systems. With regard to the soil concentrations of PPP residues in the topmost centimeters of the soil, tillage has a diluting effect on PPP residue concentration that does not occur in orchards and vineyards.

We advise to conduct the screening campaign for orchards and vineyards on a larger sample size of minimum 50 sites to gain a good understanding of the spatial variability with the goal to reduce the sample size for long term monitoring purposes. We propose to select sites for the screening reflecting area representativeness, considering only predominant cultures of orchards grouped into pomefruits and stonefruits. For both groups we select a worst-case representative culture with respect to PPP use. Apples will represent pomefruits and apricots will represent stonefruits. Fruits have two major production aims, either targeting highest table fruit quality or aiming at quantity for industrial use or use in distilleries or cider mills. With respect to PPP application the former are more intensive and will thus be selected for sampling. Vineyards will be treaten as a separate entity (Table 5). For vineyards, we aim to represent the dominant vine regions of Switzerland (Vaud, Valais, German speaking Switzerland, Ticino, and Three Lakes) and differentiate between varieties that are susceptible, robust or resistant toward diseases.

TABLE 5 ORCHARDS AND VINEYARDS IN SWITZERLAND BY AREA (BLW, 2017, BLW, 2018)

Culture	Area 2017	Rank	Part of total area		Recommended number of sample sites
	ha		Selected for sampling	Not selected	
Total	**21'067**		**94%**	**<1%**	**50**
Pomefruits	4'575		22%		**11**
Apples	3'806	2			
Pears	769	4			
Stonefruits	1'669		8%		**4**
Apricots	736	5			
Cherries	595	6			
Plums	328	7			
Peach	10	12			
Others	75			0.36%	
Kiwi	19	9			
Table grapes	19	9			
Elderflower	18	11			
Quince	9	13			
Nuts	7	14			
Minikiwi (Kiwai)	2	15			
Nashi	1	16			
Wine	14'748	1	70%		**35**

5.3.2.5 WP Vegetables

Summary WP Vegetables

- Status survey for vegetable farming
- Representative selection based on culture
- Define strategy for long-term monitoring of vegetable production

Another land-use group is vegetable production excluding greenhouses with solid foundations. Even though the management practice is similar to field crops in that growers use crop rotation, vegetable production is considerably different in other respects. Vegetable crops are often high in starch or water content, thus they are more prone to attract diseases and pests than most field crops (with the exception of potatoes and beets, which are equally vulnerable). Therefore, although the area used for vegetable growing makes only 1-3% of the total arable land, it is of special interest with regard to PPP residues in the soil. On 64% of area used for vegetable growing, producers grow "fresh vegetables" (Frischgemüse), which need to meet the highest quality standards to be directly marketable to consumers. Producers often only achieve this level of quality with intensive use of PPP. Vegetable crops are lucrative enough not to depend on extensive subsidy and thus 95% are produced under ÖLN (VSGP, 2014), which put only few more restrictions on PPP use other than GAP. ÖLN prescribes a rotation system in which one major crop of the same family can be planted no more than 2 years in succession. Furthermore, producers can often grow more than one vegetable crop on the same plot per year, adding further to the high temporal variability of PPP application. Main and short culture should ideally not be of the same family, which again adds variety to the choice of PPP. Vegetable growing is very variable, since large parts of vegetable producers (1200 out of 3100 producers) are actually agriculture producers that produce vegetables as a side business (VSGP, 2014). Nevertheless, the selection should be focused on the known vegetable growing regions of Seeland, Zurich, Aargau, the Magadino plane and the Rhinevalley, leading to at least 15 sites to achieve a statistical significant sample of 3 sites per region.

5.3.2.6 WP Soil tillage [11]

Summary WP soil tillage

- *Compare the fate and distribution of PPP residues in soils of long-term no-tillage cropland to soils under conventional and organic management*
- *Define strategy for long-term monitoring of no-tillage cropland*

Conservation agriculture is a farming system that relies on minimum or no soil tillage with the aim to sustain or even improve soil quality. Conservation agriculture has, due to the absence of tillage operations, the potential to decrease fuel consumption in agricultural production and to reduce soil erosion. Consequently, Swiss authorities promote conservation agricultural systems by awarding financial benefits to farmers practicing reduced and no tillage (FOAG, 2019). Soil tillage also affects the fate of PPP residues in the soil in various ways (Alletto et al. 2010). For instance, higher soil organic carbon content in no-tillage systems can increase retention of PPP residues by increasing soil aggregate stability and thereby decreasing PPP residues' accessibility. However, the higher persistence of PPP residues under non-tillage may be offset by the often higher microbiological activity in these soils. The fate and distribution of PPP residues in fields under reduced or no tillage is

[11] *This package is on hold until further notice.*

still poorly understood and systematic comparisons with other arable farming systems (e.g. conventional and organic farming) are lacking.

Preliminary work in the frame of an on-farm survey in 2016 assessing a total of 60 arable fields in Switzerland (20 pairs of conventional, no tillage and organically managed arable fields) revealed that no-tillage managed soils contained comparable PPP residue loads as conventionally managed fields (Riedo, Bucheli, Walder & van der Heijden et al.; in preparation). In addition, substantial numbers of PPP residues (on average 7.6 different PPP residues) were found after several years of organic management although in low concentrations. However, these observations rely on a one time-point measurement. To confirm these observations and obtain a robust and systematic overview of the prevalence and fate of PPP residues in different arable farming systems, we will repeat the soil sampling on the same field sites for an additional time point (e.g. five years later). The sites are distributed along a NE-SW transect across Switzerland covering the major pedo-climatic conditions. We will also attain a thorough description of the cropping practices including soil tillage and a detailed PPP application of the period between the two time points of sampling (2016-2021). With this detailed information on cropping practices and the PPP residues of two time points at hand, we will be able to analyses the impact of cropping practices on the fate of PPP in the context of different soil types and different PPP residue combinations. This repeated sampling will also enable us to monitor changes in PPP residues in soil and link those to changes in soil quality and soil biodiversity, including particular indicator species. Since mechanical weed control measures, such as ploughing, are omitted under conservation agriculture, herbicides, most commonly Glyphosate, are often used to combat weed pressure. Therefore, Glyphosate and its major transformation products are of specific relevance under no-tillage and will be included into the portfolio of investigated PPP residues in addition to multi-residue approach, for this work package only.

5.3.3 Indicators to assess effects on soil quality

5.3.3.1 WP reference values

Summary WP reference values

- Address feasibility of developing reference values based on a step-wise procedure for a sub-selection of substances
- Subselection of 10 substances where reference values should be determined
- Determination of the 10 corresponding reference values
- Extend development of reference values to the whole list of substances (60 to 70 substances)
- Data monitoring at NABO sites with determined reference values and selected indicators (soil risk assessment)

Ecotoxicological data for in-soil organisms regarding PPPs are still relatively scarce, compared to the ones existing for aquatic organisms. For the development of soil reference values, we will first need to investigate the quantity and quality of data available for in-soil invertebrates, microorganisms and plants. For our search, we will use existing databases (e.g. ecotox US EPA, PPDB - Pesticides Properties DataBase (University of Hertfordshire)), Pesticide Dossiers such as EFSA Draft Assessment Report (DAR) for example, and scientific publications for a sub-selection of substances (e.g. 10 substances). The sub-selection of substances will be made in accordance with the exposure modelling part of the concept. A methodology for the development of the reference values will be determined, based on the ones already existing. According to the feasibility of deriving reference values in the pilot phase and to the pertinence (i.e. representativeness for arable lands, comparison with the measured environmental concentrations) of the soil reference values derived, development will be extended to the totality of the substances listed. Accordingly, in case not enough data were available, it will be considered if additional biotests should be conducted to obtain the respective missing data. Finally, the risk will be evaluated by comparing the reference values established to the effect responses obtained from the selected indicators at NABO sites as well as with the results of the exposure monitoring (PPPs concentrations in soil).

5.3.3.2 WP Indicators

Summary WP indicators

- Set the priority regarding protection goals and soil functions required to meet soil quality criteria
- Selection of indicators according to selected protection goals and soil functions
- Survey with selected indicators at selected cropland sites of interest, proof of concept and determination of normal operating ranges (NOR)
- Data monitoring at NABO sites with selected indicators and determined reference values (soil risk assessment)

After priorizing the protection goals and the functions, which should be protected in Swiss soils, suitable indicators will be selected. The established list of bioindicators available for effect assessment (excel file appendix 7.3; non-exhaustive) will serve as basis for this purpose. It will be enhanced with data, where feasible, regarding their relation to soil functions or ecosystem services being indirictly impacted by PPPs, or any other data, like sensitivity to PPPs, costs and implementation of the indicators, that might help to decide for the selection process. This whole phasis will need comprehensive state of knowledge review as well as expert discussions.

These indicators will then be used and assessed in a pilot survey at agricultural field sites in order to define their suitability as well as the normal operating range (NOR) or the effect based threshold (EBT). If the selected indicators prove appropriate, they will be used in the monitoring phase at the NABO sites. They will be combined with the reference values calculated and monitoring results of the NABO sites (PPPs concentrations in soil) for risk assessment.

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7 Appendix

7.1 Minutes 1st Workshop

Besprechungsbetreff: 1. Workshop PSM Monitoring

Besprechungsdatum: 20.09.2018

Ort: Bern, Atelier 14B, Hauptverlag am Falkenplatz 14b, 3012 Bern

Teilnehmer

Nachname	Vorname	Einrichtung
Baur	Robert (vormittags)	Agroscope
Bucheli	Thomas	Agroscope
Campiche	Sophie	EnviBioSoil
Doppler	Tobias	EAWAG
Godbersen	Levke	Agroscope-NABO
Gubler	Andreas	Agroscope-NABO
Kasteel	Roy	Agroscope
Knauer	Katja	BLW
Lebrun	Magali	BAFU
Meuli	Reto (vormittags)	Agroscope-NABO
Schwilch	Gudrun	BAFU
Wächter	Daniel	Agroscope-NABO
Walder	Florian	Agroscope
Widmer	Franco	Agroscope
Wong	Janine	Oekotoxzentrum
Zimmermann	Michael	BLW
Prasuhn	Volker	Agroscope
Riedo	Judith	Agroscope

Protokoll

Zeit	Thema	Lead	Protokoll
09:15	Begrüssung & Einführung	BAFU & BLW	Begrüssung durch Gudrun Schwilch und Michael Zimmermann
09:30	Vorstellungsrunde jede/jeder kurz max. 3 Min; ohne Folien	EnviBioSoil & Oekotoxzentrum	
09:45	Inputs • NABO allg. (15min) • Oekotoxzentrum & EnviBoiSoil (10min) • Agroscope-Umweltanalytik (10min) • Agroscope-Aufbau (10min)	NABO	PPT befinden sich auf dem Sharepoint: https://sharepoint.admin.ch/sites/710-portal/collab/PSMMonitoring/Arbeitsdokumente/1.%20PSM-Monitoring-Workshop
10:30	Kaffee-Pause		
11:00	Referenzwerte und/oder Bioindikatoren zur Bestimmung der Bodenfruchtbarkeit	EnviBioSoil & Oekotoxzentrum	Two approaches that could be used to monitor the effects of PPPs residues on soil biocenosis and soil quality were presented: 1) the “substance-based” approach, that derives soil screening values using existing ecotoxicological data to protect the environment and 2) the “matrix based” approach that evaluates the PPP effects on soil biocenosis for sites of interest using a series of bioassays (test battery). The following questions were discussed: **1. Which approach (substance-based or matrix-based) seems to you more adapted and why?** Half of the participants (6 experts) chose the substance-based approach while the other half (7 experts) chose the matrix-based one. Most participants also expressed their interest for considering and combining both approaches. <u>Substance-based approach:</u> The arguments FOR were the following: • Quick, easy, feasible and already applicable (simpel, machbar; Schreibtischarbeit ; Umsetzung rascher machbar; EQS leichter umsetzbar; bereits anwendbar; vollzugstauglich) • Quantifiable and comparable (absolut messbar in Zahlen; vergleichbar)

			• Methodologies already available (gibt etablierte Methoden; nationales Vorgehen; Daten/Info vorhanden; analog zu Vorgehen beim Wasser; Boden EQS: Besser etabliert, mehr Rückschlüsse auf Ursachen nötig) The arguments AGAINST were the following: • Expensive and non specific (Aufwendig; generisch) • Data and tests missing (Datenlücken; Tests fehlen) • Problem of mixture (nur für einzelne Substanzen; Mischeffekte unklar) • Limited (einige wenige Substanzen messbar) • Representativeness (wenig link zu Effekten im intakten Boden; kein Abbild des Bodenökosystems; Diskrepanz zur effektiven Umweltsituation) <u>Matrix-based approach:</u> The argument FOR were the following: • holistic approach (Integration über alle Substanzen, ganzheitliche Sicht auf die Effekte, Boden wird ganzheitlich betrachtet, allg. (PSM-abhängige) Betrachtung) • realistic assessment of a complex matrix (Interaktionen zw. Matrix und Organismen, spiegelt Realität wieder, berücksichtigt Komplexität, Resilienz, Matrix basiert für monitoring, da Konzentrationen schon vorhanden sind, wertvolle Zusatzinfo) The arguments AGAINST were the following: • expensive (teuer) • laborious and time-consuming (aufwendig, viel Arbeit notwendig, lange Entwicklung) • information and experience missing (wenig Info, Erfahrung fehlt) • not well developed (noch wenig ausgereift) • too complex (zu viele beeinflussende Faktoren) • execution difficult (Umsetzung/Vollzug schwierig) Matrix based approach alone: • no direct connection to single substances possible (zu wenig Rückschluss auf PSM möglich, Abgrenzungseffekt-> Erfolgskontrolle von PSM Reduktion nicht sehbar) Integrative approach of both methods:

<table>
<tr><td></td><td></td><td></td><td>complement each other well (ergänzen sich sehr gut)
broader gain of knowledge (grösseres Lernpotential im Rahmen der Statusaufnahme)
The following considerations and remarks were also expressed:
Terrestrial Model Ecosystem (TME) could be of interest and would be appropriate for the matrix-based approach
Leachates/soil solution (Lysimeter) should also be considered
Variability for field testing (mesocosms) is higher than for lab testing
The Matrix-based approach would need a validation
2. Should we investigate effects only in-field or also off-field? (function / biodiversity)
The question was discussed in Plenum. It was agreed that effects should primarily be investigated in-field but that off-field areas within the vicinity of the fields such as ecological compensation areas (Biodiversitätsförderflächen), buffer zones and field's edges should also be considered.

Potential synergies with the other working groups (e.g. Gewässerschutz, Biodiversität…) dealing with the "off-field" thematic must be discussed.

The following points were also discussed:
Interest of having 2 soil screening values: in-field and off-field? (to be discussed)
Protection goals for in-field and off-field are different and are within the competence of the policy-makers (political decisions)
3. Which organisms should be considered (in-soil organisms including microorganisms, plants, NTA, others…)

General agreement was made on in-soil organisms, microorganisms and plants.</td></tr>
<tr><td>12:30</td><td>Mittagessen UNIESS Bistro Bar Lounge (offeriert)</td><td></td><td></td></tr>
<tr><td>13.30</td><td>Kaffee</td><td></td><td></td></tr>
<tr><td>14:00</td><td>Konzept Monitoring PSM-Rückstände in Böden
Input: Entwurf Konzept der NABO</td><td>NABO</td><td>Vorstellung des Monitoring- und Screeningkonzeptes
Anschliessend wurden folgende Fragen zur Diskussion gestellt.
1. Was sind die Ziele des Monitorings in Böden? (Plenum)</td></tr>
</table>

	• Diskussion		• Als Ziel der Langzeitbeobachtung wurde die Darstellung der PSM Konzentrationen in landwirtschaftlich (inkl. Wein-, Gemüse-, und Obstbau) genutzten Böden identifiziert. Böden aus Forsten und Naturschutzflächen wurden explizit ausgeschlossen. Böden in Agglomerationsräumen wurden nicht erwähnt.
			• Exaktere Begriffsdefinition von Bodenfruchtbarkeit als Schutzziel notwendig, vorzugsweise unter Bezugnahme auf die vorhandenen Definitionen aus der Zulassung und Gesetzgebung.
			• Die Langzeitbeobachtung wird von der Zulassung als nützliches messwertbasiertes Feedback zum Risikomanagement in der Zulassung gesehen.
			
			2. Auswahl von relevanten Pflanzenschutzmitteln und Abbauprodukten (in Gruppen)
			
			• Nach welchen Kriterien soll die Auswahl an PSM für die kommenden Screenings ausgewählt werden?
			• Welche Kriterien muss ein Stoff erfüllen, damit er in einer Langzeitbeobachtung geführt werden muss?
			
			Genannt wurden folgende Auswahlkriterien wobei es hinsichtlich der Priorität unterschiedliche Auffassungen gab:
			• Persistenz (lange DT50)
			• Akkumulationsneigung (hohe Kfoc Werte)
			• Substanzen, welche in der Risikobewertung der Zulassung ins Higher Tier kamen
			• Substanzen, welche in hohen Mengen und grosser Häufigkeit angewendet werden
			• Substanzen mit herausragender (Öko-)toxizität
			• PSM mit besonderem Risikopotenzial laut Anhang 9.1 des Aktionsplans Pflanzenschutzmittel, als Kontrollinstrument der Zielstellung 5.7 im AP PSM
			  • ***Leitziel*** • **Die Anwendung der PSM hat keine langfristig nachteiligen Auswirkungen auf die Bodenfruchtbarkeit und der Einsatz von PSM mit für den Boden ho-hem Risikopotenzial wird reduziert.**
			  • *Zwischenziel 1* • Rückstände relevanter PSM in Böden und deren Abbauprodukte sind bis 2020 be-kannt und werden ab 2020 regelmässig überprüft.
			  • *Zwischenziel 2* • Die Anwendung von PSM mit einer Persistenz im Boden (DT50 > 6 Monate)10 wird bis 2027 um 50% gegenüber der Periode 2012-2015 reduziert.
			• Nur solche welche aktuell zugelassen sind

- Regelmässige Überprüfung der Liste der beobachteten Stoffe, um auf Neuzulassungen und signifikante Änderungen der Verkaufszahlen (Top 20 Listen) reagieren zu können
    - Adaption soll mit zeitlicher Verzögerung erfolgen, um Abverkauf und Aufbrauchen vorhandener Bestände einzuschliessen
- Substanzen, die aufgrund der üblichen Fruchtfolgen zu erwarten sind
- Analytische Messbarkeit
- Berücksichtigung regionaltypischer Anwendungshäufigkeit (z.B. Wein, Obst, Gemüsebauregionen), welche vom nationalen Verteilungsmuster abweichen.

Es werden Daten von Abbauprodukten (TP) im Boden mit folgenden Kriterien gewünscht:

- TP > 5% AR des Parents (Wobei im Labor gemessene TP nicht immer die Situation im Feld wiederspiegeln)
- Beschränkung auf laut Verordnung (öko-)toxikologisch relevante Abbauprodukte
- Persistenz (lange DT50)
- Akkumulationsneigung (hohe Kfoc Werte).

Folgende Stoffe oder Stoffgruppen wurden gezielt hervorgehoben:

- Organophosphate und Pyrethroide (Substituenten für nicht mehr zugelassene Neonicotinoide)
- Chlorpyrifos.

Es wurde vorgeschlagen, neben der gezielten Analyse einzelner Wirkstoffe und TP eine breite Analyse ohne ausgewiesene Wirkstoffe zu machen, um auf Stoffe aufmerksam zu werden, die in der ausgewiesenen Liste zwar nicht genannt wurden, aber dennoch aus welchen Gründen in hohen Mengen im Boden vorkommen.

3. Anforderungen an das Standortkollektiv (In Gruppen)

- Wie muss das Standortkollektiv für die Langzeitbeobachtung zusammengestellt sein?
- Wie können Fragestellungen in PSM-intensiven Kulturen bearbeitet werden?

Die beiden Gruppen hatten unterschiedliche Vorstellungen, wie eine Statuserhebung bezüglich PSM durchgeführt werden soll:

- Eine Gruppe war der Meinung, genaue Daten zu Applikationsmengen und –daten seien nicht nötig, es solle ein möglichst breites Kollektiv unter Berücksichtigung KABOs, ZA-AUI und

			weiteren Messnetzen genutzt werden (allerdings werden Ressourcen für Probeahme & Analytik wohl begrenzt sein). • Die zweite Gruppe erachtete Standorte, wo Applikationen nicht bekannt sind, als unbrauchbar, die gemessenen Konzentrationen sind nicht interpretierbar (damit sind v.a. ausgewählte KABO-Standorte und ZA-AUI mögliche Ergänzungen). Daneben sind Bodeneigenschaften und Klimadaten wichtig. Lieber weniger Standorte, dafür interpretierbar. • Probenahme im Netz von ZA-AUI wurde von beiden Gruppen als Option genannt, sofern sich dort eine Möglichkeit ergibt. • PSM-intensive Kulturen wie Obst- Reb- und Gemüsebau müssten auch betrachtet werden, allerdings nicht nur eine Region, da grosse Unterschiede zwischen Regionen (Boden, Klima, landwirtschaftliche Praxis). • Zeitlich hochaufgelöste Beprobung wurde als Option genannt, um Jahresverläufe und Konzentrationsspitzen zu erkennen. Deshalb auch nicht nur nach Winter beproben, da dann tiefste Konzentrationen erwartet werden.
15:30	Zusammenfassung & Schlussdiskussion	EnviBioSoil & NABO & Oekotoxzentrum	Rückmeldungen zum Workshop und zum Konzept • Offene und vertrauensvolle Diskussion wurde sehr geschätzt • Breite Expertise im Forum wurde sehr geschätzt • Notwendigkeit zur Fokussierung und Definition des Schutzziels • Die Zulassung erhofft sich Feedback zu Konzentrationen von PSM im Boden und besseres Verständnis der Bodenfruchtbarkeit als Schutzziel • Besseres Einbeziehen von Stakeholder: z.B. Bauernverband, Industrie, NGOs ○ Wie können Landwirte von den Ergebnissen des Monitorings profitieren • Internationale Synergien sollen von Beginn an genutzt werden • Klarstellung des Probenahmezeitpunktes • Indikatoren der Bodenfruchtbarkeit als wichtiges Instrument zur Quantifizierung wahrgenommen • Relevanz der PSM für Bodenfruchtbarkeit allerdings fraglich, andere Faktoren haben wahrscheinlich viel grösseren Einfluss • Regelmässige Information der Steuergruppe Boden-Wasser und der Vollzugsgruppe Bodenbiologie wurde gewünscht • Der der vorhandene Sharepoint soll als Informationsplattform innerhalb der Begleitgruppe genutzt werden • Unklarheit besteht noch darüber, wer die Teilnehmer der Begleitgruppe sind
16:30	Ende der Veranstaltung		

7.2 Minutes 2nd Workshop

Subject: 2nd Workshop on Monitoring of Plant Protection Products in Soils
Date: 19.11.2018

Place: Swiss Federal Institute for Technology (ETH), HG F 33.1, Rämistrasse 101, 8092 Zürich

Participants:

Name	Firstname	Institute
Baur	Robert	Agroscope
Brugger	David	Bauernverband
Bucheli	Thomas	Agroscope
Campiche	Sophie	EnviBioSoil
Chiaia-Hernández	Aurea	Uni Bern
dela Peruta	Raniero	Agroscope-NABO
Deriaz	Nathanael	DGAV Kt. VD
Ferrari	Benoît	Oekotoxzentrum
Frey	Beat	WSL
Füglistaller	Dominik	Berner Fachhochschule
Gassmann	Sebastien	Kanton Genf
Godbersen	Levke	Agroscope-NABO
Gubler	Andreas	Agroscope-NABO
Gygax	Michel	LANAT
Hilber	Isabel	Agroscope
Höfliger	Basil	Agroscope-NABO
Hofman	Jakub	Recetox, CZ
Hug	Anna	Agroscope-NABO
Kasteel	Roy	Agroscope
Keller	Armin	Agroscope-NABO
Knauer	Katja	BLW
Kobierska-Baffie	Florian	Agroscope
Lebrun	Magali	BAFU

Mangold	Simon	Agroscope
Martin-Laurent	Fabrice	INRA
Meuli	Reto	Agroscope-NABO
Mougin	Christian	INRA Versailles, France
Poiger	Thomas	Agroscope
Riedo	Judith	Agroscope
Römbke	Jörg	ECT Oekotoxikologie GmbH
Schmutz	Daniel	Kanton Baselland
Schwilch	Gudrun	BAFU
Screpanti	Claudio	Syngenta Crop Protection Muenchwilen AG
Steffens	Markus	FIBL
Strahm	Iwo	BLW
Sybertz	Alexandra	RWTH Aaachen (D)
Vera	Silva	Wageningen UR
Wächter	Daniel	Agroscope-NABO
Waespe	Jan	BLW
Werner	Inge	Oekotoxzentrum
Westermann	Stéphane	VS, Dienststelle für Umwelt
Wettstein	Felix	Agroscope
Widmer	Franco	Agroscope
Wong	Janine	Oekotoxzentrum
Zimmermann	Michael	BLW

Time	Topic	Lead	Protocol
09:00	Registration and Coffee		
09:30	Welcoming / Introduction	FOAG FOEN	Introduction by Gudrun Schwilch and Michael Zimmermann PPT are available from the sharepoint: https://sharepoint.admin.ch/sites/710-portal/collab/PSMMonitoring/Arbeitsdokumente/1.%20PSM-Monitoring-Workshop

09:40	Monitoring of Plant Protection Products (PPP) in Soils • PPP Monitoring on EU Soils Vera Silva (WUR, Wageningen University and Research, The Netherlands)	NABO	Issues discussed following the first presentation: • The importance of having the application data/farmer's records when collecting soil samples for PPP analysis was emphasized. • In the presented study compound measurements were exceeding the calculated range from PEC data in some cases (data taken from EFSA, for all available scenarios) - Possible reasons for the exceedance: PEC calculations too conservative, higher application rates used, additional input through erosion… - The underestimation of the occurring risk if PECs were too conservative was mentioned as a main resulting problem.
	• PPP Monitoring of Soils and Risk Assessment in the Czech Republic Jakub Hofmann (Recetox, Czech Republic)		Issues discussed following the second presentation: • Selection of compounds and transformations products for analysis: - Analytical limitations are a big issue, also for transformations products - In CZ lack of experience for measurements of several selected transformation products in soil lab, collaboration with water lab, verification of their methods for soil? - When sampling soil in early spring rather transformation than parental products to be expected in the samples • Measurement of high concentration compounds vs. multi residues analysis - Importance of communicating that some important compounds (e.g. Glyphosate) were not measured in study when presenting the risk assessment results
10:40	Break		
11:10	Monitoring of Plant Protection Products (PPP) in Soils • Concept for Monitoring PPP in Switzerland, based on the activities of the Swiss Soil Monitoring Network ○ Selecting Targets ○ Selecting Sites Levke Godbersen (NABO, Switzerland)	NABO	Issues discussed following the presentation: It was argued whether background/long-term concentrations or peaks of PPP should be the target of the monitoring: • Arguments for background concentration measurements - Objective stated in action plan = background/long-term concentration, get broad picture of situation in CH, different sites, land-use types, soil types… - NABO responsible for long-term soil monitoring, 5 year intervals, peak measurements not possible

	• Discussion		• Arguments for peak measurements: - Used in pesticide admission, worst-case approach as standard procedure in risk assessment - Potential knock-down effect of peaks on soil organisms - Society might ask for impact on human health or on ground-water→interest in peaks - Current direction of PPP development towards reduction of long-term residues-> sense of sampling for long-term concentration? • Additional suggestions: - Combining different measurements intervals/different target concentrations: e.g. 5 year and 1 year intervals - Other projects responsible for peak measurements, e.g. hydrological shortcuts - Regional differences in PPP use within Switzerland were explained (by M.Gygax): • Up to 85-90% no regional differences, generally high amounts of potatoes, sugar beet, rape… • Around 80 % of farmers have up to 5 years grassland within their rotation (no PPP input during this period) • Type of farm: extensive vs. intensive • Some hotspots: e.g. vegetables (e.g. Seeland and Rheintal St.Gallen) or vineyards and orchards (Valais and Vaud). Concentration of potatoes (Berne), concentration of sugar beets (Frauenfeld, Aarberg) • Considering hotspots for sampling design, when plot size only 10m^2, taking also samples in surroundings? Additional suggestions which were made concerning the sampling design: • Plot size: CH NABO standard 10m^2, CZ standard 100m^2, found to be ideal for heavy metal, in CH smaller field size, 100m^2 too big, →including plot size in communication of the results) • Considering the variability of PPP distribution within a field (inserting rows and in-between rows in sampling plot) • Using extensive grassland sites as control, not excluding them totally from survey • Taking the cropping system into account (IP, Bio…) • Including not intended dispersions (wind erosion, run off…), e.g. considering landscape relief to minimize background noise. (in CH pilot study some not applied PPP have been found)

			• Sampling depth (only first 20 cm or also deeper samples up to 40 cm, considering differences in agricultural practices e.g. between Valais and Berne, underestimation in no ploughing systems (e.g. permanent cultures. EU guidance for soil exposure modelling prescribes 0-5 cm for permanent cultures to avoid dilution. • Difference between farms with/without animals (difference in soil biodiversity? Need for specialisation not only influencing farmers but also soils?) • After sampling treatment of soil (loss of information by drying? drying at 40° or direct freezing) • Using in-field passive samplers as for water (known from other organic pollutants studies that even less developed than lab analytical methods) • Precision agriculture (Considering potential reduction of PPP in long-term scenarios) • Yield (measuring yield from sampled plots, so far only estimated) • Importance of application data (available in CH via e.g. Nabo Flux)
12:00	Lunch Foyer (HG EO Süd)		
13.30	Approaches to protect soil biocenosis I • Pesticidovigilance in agricultural soils: indicators of soil ecosystem functions? Fabrice Martin-Laurent (INRA, France) • Monitoring of soil invertebrates: recent developments in Germany and the European Union Jörg Römbke (ECT, Germany)	EnviBioSoil & Oekotox-zentrum	Some outcomes of the first workshop were presented by J. Wong: • Using combination of substance- and matrix-based approach for the evaluation of PPP effects in Switzerland • Main focus on in-field effects; margins, buffer zones, ECA should be considered through • Focusing on effects on MOs, in-soil invertebrates and plants Issues discussed following the first presentation: • Detection by action vs. detection by compound ? Transferability of results from Nicosulfuron? • Significance of older biological indicators (e.g. microbial biomass)? Easy to measure, but difficult to assess influence of PPP: half of biomass might be killed by PPP, but replaced by necrotrophic species→same total amount, i.e. no change in the total biomass. Same problem with respiration measurements, not sensitive enough, therefore skipped by EFSA • Presence of pesticide-tolerant MOs: Positive sign of recovery after pesticide use? Overall yes, but unknown costs of adaptation, potentially reduced resistance to further stress, reduced diversity • Time period unclear until irreversible effects on MO-community occur (→required duration of the monitoring program?)

			- For atrazine, degraders have been detected only after 50 years, for glyphosate shorter time period, depends on compound - Combining long-term monitoring with shorter intervals for compounds with low persistence? • Additional suggestions: - Including off-field areas for bio indicators to have comparison for in-field values - Considering measurements of antibiotic residues on farms with animals - Considering effects of semiochemicals in survey Issues discussed following the second presentation: • Molecular methods will replace classical taxonomy Better resolution of data of DNA coming of eDNA samples for specific species • Microbiological methods Good methods for some functional groups e.g.nitrogen cycling, for others not e.g. carbon cycling • Stability of DNA in soil? Distinction of living/dead organisms for molecular methods? No known answer yet, however DNA is quite stable • Litterbag method: why not mentioned in presentation? Taken out of guidelines due to lack of sensitivity, every organic material degraded at some point, cut-off value for time needed…. • Crop centred approach (healthy soil →healthy crops), using the crop as indicator, use of remote sensing? - Crop health not always reliable indicator (e.g. Chlordecone in FR), late reaction - Easy-to use approach for diverse sites needed, e.g. eDNA linked with crop yield • Functional tests in field: exclusion of natural variations (moisture, temperature…) - Using control with similar environmental conditions - Linking results with soil property, region… - Small scale effects cannot be completely eliminated • Soil and water monitoring should learn from each other • Planed German soil biological monitoring: target to assess background MOs in the soil as reference value, not to monitor directly the influence of PPP (maybe latter useful for this purpose)
14:30	Approaches to protect soil biocenosis II	EnviBioSoil &	Suggestions on good indicators for soil quality, mainly in field, were collected: • Organisms should be sensitive to PPP but not to other disturbances like ploughing, etc

	• Concept for evaluating the risk of PPP residues to soil quality
	  • Derivation of soil screening values
	  • Use of bioassays to evaluate the effects of PPP on soil biocenosis (test battery).
	
	Discussion
		Oekotox-zentrum	Specific species for biodegradation/decomposition known, for other functions not
			• Also considering functional traits of MOs not only diversity:
			- Ecotoxicology: important to know which factors/functions are most important for soil quality→ make a list, e.g. nitrogen cycling, then identify which MOs contribute to these selected functions -> suitable bioindicators
			- On the other hand: protecting biodiversity-> functions will be protected automatically (diversity already declines before function)
			• Making difference between indicators for soil quality in general or influence of PPP on it (also other influential factors like compaction)
			  o →making long-term monitoring to assess normal state
			- Important to have reference what is normal, what is good/bad,
			  o NOR (normal operating range) needs to be determined
			- Maybe also take a reversed approach: define what is not wanted, e.g. by looking at contaminated sites
			• Reference approach, included in long EFSA opinion paper (specific type, history, region, properties should host similar organisms known for water systems should also apply to soil→distinctive sites, distinctive groups of organisms
			  - Comparability of aquatic and terrestrial ecotoxicology?
			  - For species rich groups e.g. mites more difficult
			• Soil organic carbon: directly addressing SOC?, expectation that PPP absorb to SOC, the MOs easily killed, SOC rich soils more easily destroyed by PPP
			Further comments on soil quality:
			• Target in action plan? Soil fertility or quality?
			Defined target is how do PPPs change soil fertility
			Sufficient as target? How is soil fertility defined?
			• Current significance of soil biodiversity for farmers:
			- In CH Landwirtschaft Biodiversität im Boden aktuell kein Thema, in NFP 68 erstmals genauer umschrieben, viele offene Fragen. zahlreiche Einflüsse wie Bearbeitung, Bodeneigenschaften..., viele grundlegende wissenschaftliche Fragen nicht geklärt, schwierig
			- On the other hand when talking to farmers during collecting campaigns, earthworms important sign for them for soil functioning, many farmers already use very simple methods like spade and counting amount of earthworms for rough assessment of the soil→some awareness present

			It was discussed whether a combined approach lab and field, a tiered approach, is needed or if field alone is sufficient. • Not necessary to go directly to the field, to the highest level of complexity, clear answer on lower tier can save money, is more flexible • Clear objective and clear hypothesis are needed to go from lower to higher tier
15:45	Closing remarks		
16:00	End of the Workshop		

7.3 Biological indicators for effect assessment

The main biological indicators available to assess effect of substances on in-soil organisms are listed in the attached excel file. They can be sorted, for example, according to the organisms (e.g., micoorganisms, earthworms, plants…), species name, endpoints (measured parameters) or methods of interest. The link between the listed bioindicators and the potential functions or ecosystem services they provide that might be impacted by PPPs is not established here as it still requests further considerations, reviews and discussion. It will be an important starting point for the selection the bioindicators for the development of the effect monitoring.

7.4 Cost estimation

For an overview of financial resources needed to complete abovementioned work to develop the nationwide exposure monitoring and effect monitoring of PPP residues in Swiss soils within the anticipated timeframe, please refer to the respective related documents.