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Pathways for advancing pesticide policies

Colloqium of the Institute of Science, Technology and Policy.
27.10.2020

Robert Finger & Niklas Möhring
Agricultural Economics and Policy Group ETHZ
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Agricultural Economics and Policy

Agenda

- Framing the problem
- A framework for advancing pesticide policies
- Key steps to achieve a reduction in pesticide risks
- Case study: Pesticide free wheat production in Switzerland

Framing the problem

- Pest management is critical for food security (e.g. Savary et al. 2019, Oerke 2006)

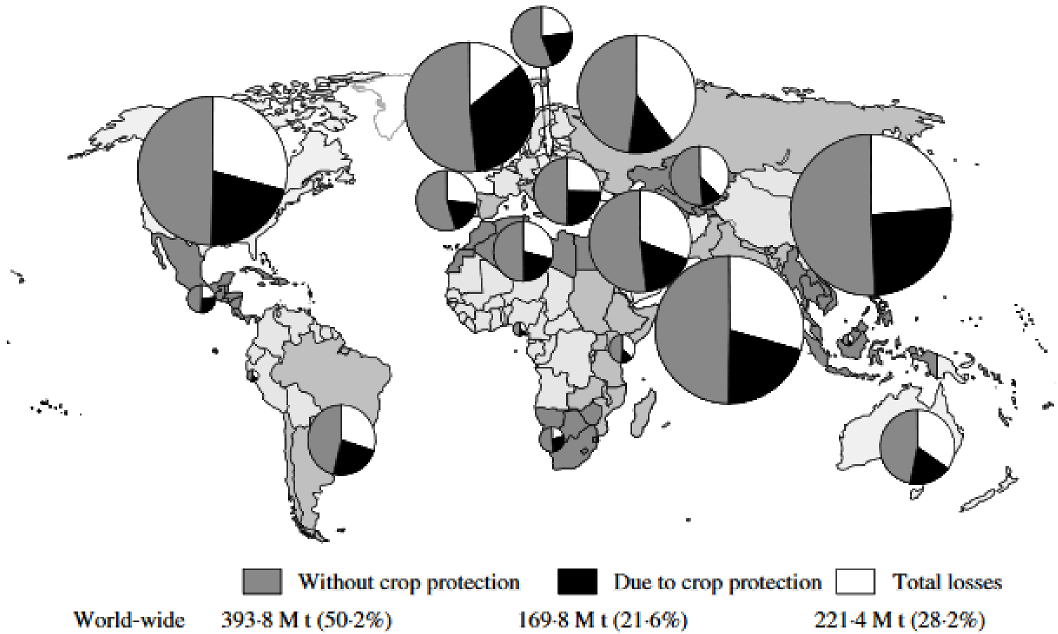

Fig. 3. Estimated contribution of actual crop protection (mechanical, biological, chemical) in safeguarding wheat production, by region, in 2001–03 (size of pies corresponds to attainable production).

Savary, S. et al. The global burden of pathogens and pests on major food crops. *Nat. Ecol. Evol.* **3**, 430–439 (2019).
Oerke, E. C. (2006). Crop losses to pests. *The Journal of Agricultural Science*, *144*, 31.

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Framing the problem

- Demand for pest management is increasing, e.g. due to consumer preferences and climate change (e.g. Deutsch et al., 2018)

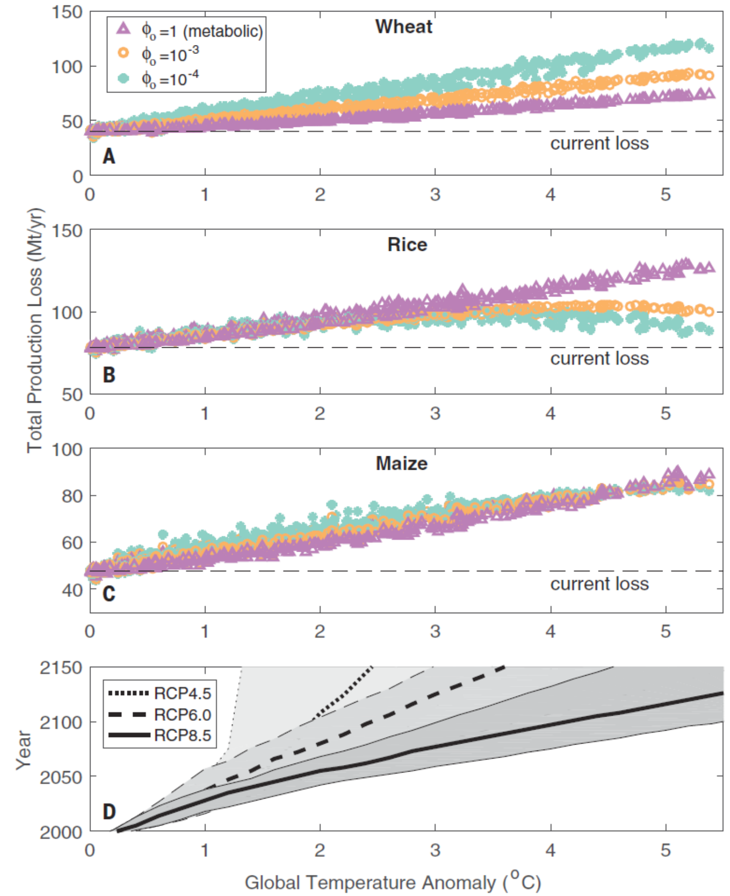

Fig. 1. Global loss of crop production owing to the impact of climate warming on insect pests. Crop production losses for (**A**) wheat, (**B**) rice, and (**C**) maize are computed by multiplying the fractional change in population metabolism by the estimated current yield loss owing to insect pests, summed over worldwide crop locations. Results are plotted versus mean global surface temperature change, for four climate models (*13*), for two different values of the demographic parameter governing survival during diapause (ϕ_o = 0.0001, asterisks; ϕ_o = 0.001, circles), and for the metabolic effect alone (triangles). Mt/yr, metric megatons per year. The year in which a given global mean temperature anomaly is reached (**D**) depends on the greenhouse gas emissions scenario (RCP, representative concentration pathway) and varies across models (shading) owing to uncertainty in climate sensitivity to those emissions (*13*).

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Deutsch, C. A., Tewksbury, J. J., Tigchelaar, M., Battisti, D. S., Merrill, S. C., Huey, R. B., & Naylor, R. L. (2018). Increase in crop losses to insect pests in a warming climate. *Science*, *361*(6405), 916-919.

Framing the problem

- But: adverse effects of pesticides on human health and the environment (e.g. Larsen et al., 2017, Stehle and Schulz, 2015)
- Reduction of potential risks from pesticide use explicit goal for policy and industry
  - National Action Plans to reduce risks and impacts of pesticide use on human health and the environment in most European countries (e.g. Directive 2009/128/EC).

- Little evidence that Europe has achieved the reduction in pesticide risks
  - A direct assessment of policy targets proves difficult, as most European countries do not publish or monitor data on risks (European Court of Auditors (2020)
  - Surface and groundwater contamination still regularly exceed legal thresholds (e.g. Stehle and Schulz, 2015, Spycher et al., 2018)
  - Societal concerns remain

Larsen, A. E., Gaines, S. D. & Deschênes, O. Agricultural pesticide use and adverse birth outcomes in the San Joaquin Valley of California. *Nat. Commun.* **8**, 302 (2017).
Stehle, S. & Schulz, R. Agricultural insecticides threaten surface waters at the global scale. *Proc. Natl Acad. Sci. USA* **112**, 5750–5755 (2015).
European Court of Auditors (2020) *Special Report 05/2020: Sustainable Use of Plant Protection Products: Limited Progress in Measuring and Reducing Risks*
Spycher, S. et al. Pesticide risks in small streams—how to get as close as possible to the stress imposed on aquatic organisms. *Environ. Sci. Technol.* **52**, 4526–4535 (2018).

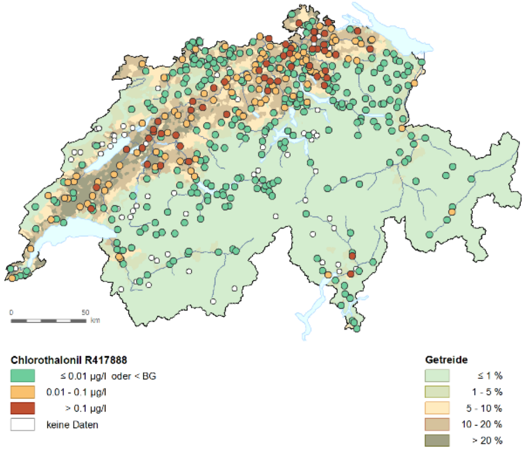
Example Switzerland – pollution of water bodies

Eine Million Schweizer haben Pestizide in ihrem Trinkwasser: Was wir wissen - und was nicht

Bruno Knellwolf / CH Media - zuletzt aktualisiert am 01.09.2020 01.09.2020 13:13 0 11

Pestizid im Trinkwasser: In der Schweiz sind eine Million Menschen davon betroffen. © CH Media

- Unser Trinkwasser kommt zu 80 Prozent aus dem Grundwasser.
- In mehr als der Hälfte der Kantone ist das Grundwasser mit Abbauprodukten des Pestizids Chlorothanonil belastet.



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Munz, N., Leu, C., & Wittmer, I. (2012). Pestizidmessungen in Fliessgewässern. *Aqua und Gas*, *92*(11), 32.
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Kiefer, K., Bader, T., Minas, N., Salhi, E., Janssen, E. M. L., von Gunten, U., & Hollender, J. (2020). Chlorothalonil transformation products in drinking water resources: Widespread and challenging to abate. *Water Research*, *183*, 116066.

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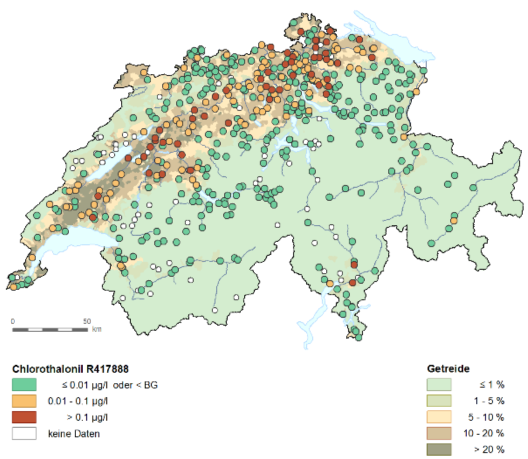
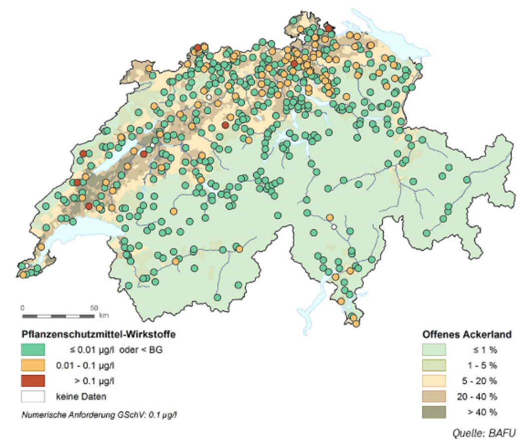


Probenahmen am Eschelisbach (TG). © Esther Michel, Eawag

von **Stefanie Wermelinger**

Zwei Studien zeigen erneut, dass Gewässer in landwirtschaftlich genutzten Einzugsgebieten stark mit Pflanzenschutzmitteln belastet sind. Die Konzentrationen einzelner Stoffe stellen über Monate hinweg ein Risiko für chronische Schäden der Pflanzen und Tiere im Wasser dar.



PSM-Wirkstoffe im Grundwasser (2017) sowie offenes Ackerland. Maximalwert pro NAQUA-Messstelle. © BAFU

Bild 1 / 3

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Example Switzerland – two popular initiatives

2bis Der Einsatz synthetischer Pestizide in der landwirtschaftlichen Produktion, in der Verarbeitung landwirtschaftlicher Erzeugnisse und in der Boden- und Landschaftspflege ist verboten. Die Einfuhr zu gewerblichen Zwecken von Lebensmitteln, die synthetische Pestizide enthalten oder mithilfe solcher hergestellt worden sind, ist verboten.

Initiativtext

Eidgenössische Volksinitiative
«Für sauberes Trinkwasser und gesunde Nahrung – Keine Subventionen für den Pestizid- und den prophylaktischen Antibiotika-Einsatz»

Unser wichtigstes Lebensmittel ist das Trinkwasser. Es entsteht zum grossen Teil durch die Versickerung des Regens dort, wo auch unsere Nahrung wächst, auf landwirtschaftlich genutzten Böden. Diese Böden sind der beste Trinkwasserfilter und ein grosser Wasserspeicher. Unsere heutige intensive Landwirtschaft setzt riesige Mengen an Pestiziden, Antibiotika, Importfutter und Düngemittel ein. Das bedroht die Qualität unseres Trinkwassers und unserer Nahrung sowie die Biodiversität, das Klima und die Luft. Und gefährdet die Gesundheit und die Ernährungssicherheit von uns.

Kernthemen der Initiative

- Antibiotikaresistente Bakterien
- Zu viel Gülle
- Pestizidfreie Produktion
- Biodiversität
- Bildung – Forschung – Investitionshilfen

Huber, R., Finger, R. (2019). Popular initiatives increasingly stimulate agricultural policy in Switzerland. EuroChoices 18(2): 38-39

Example Switzerland – public interest in ‘pesticides’

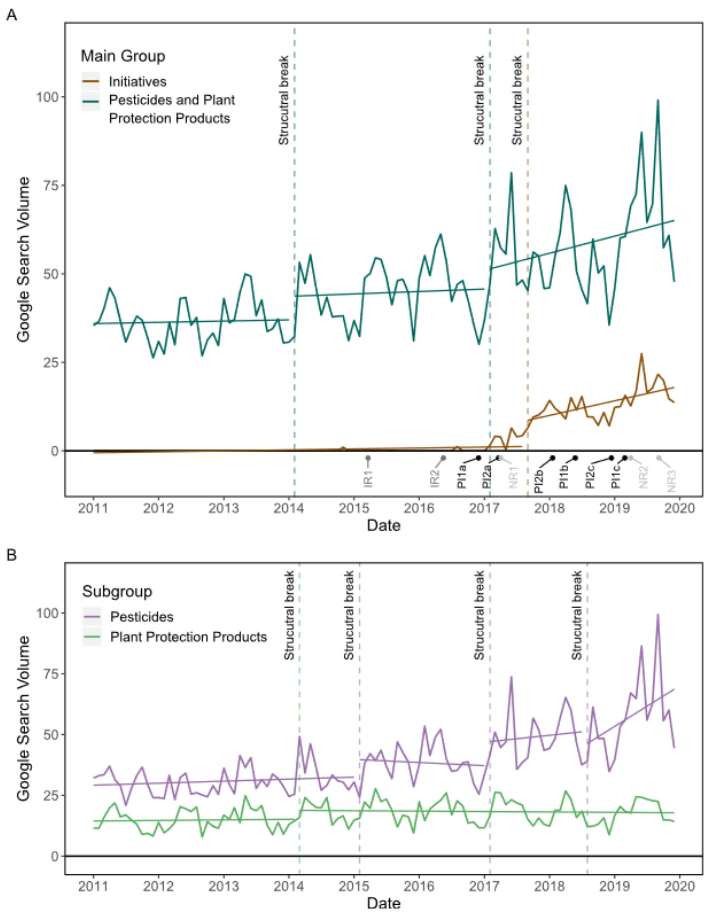

Figure 1. Public interest over time (measured in relative search volume) for search terms related to pesticides, plant protection products and the popular initiatives in Switzerland. Panel A shows public interest over time in the two main groups of search terms (pesticides and plant protection products as well as initiatives). Related political activities and report releases are indicated by abbreviations. In detail, PI1 indicates activities related to the popular initiative ‘Save Switzerland from Synthetic Pesticides’, while PI2 relates to the popular initiative ‘Clean Drinking Water and Healthy Food’. Lower-case letters refer to the political process of popular initiatives, i.e. start of collecting signatures (a), initiative submission (b) and publication of the response by the Swiss Federal Council (c). NR1 and NR2 indicate national report releases by the Swiss Federal Institute of Aquatic Science and Technology and NR3 by the Swiss Association of Cantonal Chemists. IR1 and IR2 indicate the international UN reports. Panel B shows public interest in the subgroups of search terms over time (pesticide as well as plant protection products).

- Increased public interest in ‘pesticides’ and ‘plant protection products’ (panel A)
- This can be attributed especially to pesticides → linked to negative connotation (panel B)
- Trend visible before popular initiatives were launched
- Similar trends in France, but not in Germany, Austria and Italy (not shown)

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Schaub, S., Huber, R., Finger, R. (2020). Tracking societal concerns on pesticides – A Google Trends analysis. Environmental Research Letters 15 084049

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Our goal

- Describe pathways to a successful reduction of potential risks from agricultural pesticide use
- Avoid reducing other ecosystem services provided by agricultural production
- Develop a holistic, interdisciplinary framework that spans across various actors along the value chain

nature food

PERSPECTIVE

https://doi.org/10.1038/s43016-020-00141-4

Check for updates

Pathways for advancing pesticide policies

Niklas Möhring[1] ✉, Karin Ingold[2,3], Per Kudsk[4], Fabrice Martin-Laurent[5], Urs Niggli[6], Michael Siegrist[7], Bruno Studer[8], Achim Walter[9] and Robert Finger[1] ✉

Numerous pesticide policies have been introduced to mitigate the risks of pesticide use, but most have not been successful in reaching usage reduction goals. Here, we name key challenges for the reduction of environmental and health risks from agricultural pesticide use and develop a framework for improving current policies. We demonstrate the need for policies to encompass all actors in the food value chain. By adopting a multi-disciplinary approach, we suggest ten key steps to achieve a reduction in pesticide risks. We highlight how new technologies and regulatory frameworks can be implemented and aligned with all actors in food value chains. Finally, we discuss major trade-offs and areas of tension with other agricultural policy goals and propose a holistic approach to advancing pesticide policies.

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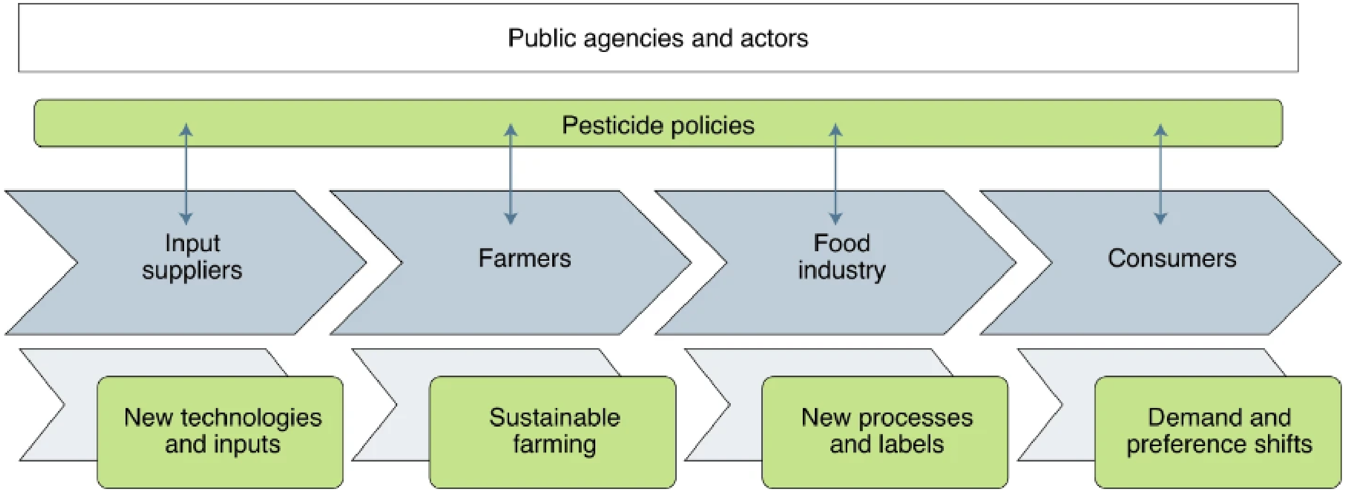
A framework for pesticide policies

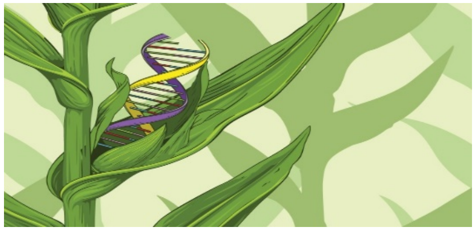


Pesticide policies interact with input suppliers, farmers, the food industry and consumers – each actor can contribute towards sustainable food systems with actions specific to their role (bottom row). Current policy measures can be classified as command and control measures (for example, pesticide authorization, bans and use regulations), market-based measures (for example, pesticide taxes, financial support of new technologies and direct payments) and information-based measures (for example, education, labelling and awareness raising). Many specific, national or regional measures are contained in each of the three categories and may target conflicting policy goals[78].

Ten key steps to achieve a reduction in pesticide risks

- Policy indicators, targets and design
  - Tangible pesticide risk indicators
  - Dimensions of policy targets
  - Realignment of agricultural policy goals

- Farmer and consumer actions
  - Farmer decision-making processes
  - Consumer choices and preferences



- Sustainable plant protection
  - Pesticide admissions and regulations
  - Sustainable farming systems
  - Plant breeding strategies
  - Smart farming
- Efficient and dynamic pesticide policy portfolio

→ A holistic approach to pesticide policies

Example 1: Tangible pesticide risk indicators

- Country-specific reduction goals for potential environmental and health risks. Specific and measurable targets needed – but lacking for almost all countries.

- Purely quantitative indicators (e.g. reduction of tons of pesticide use) alone not necessarily correspond with potential environmental and health risks (Möhring et al., 2019)

Möhring, N., Gaba, S. & Finger, R. Quantity based indicators fail to identify extreme pesticide risks. *Sci. Total Environ.* **646**, 503–523 (2019)
Kudsk, P., Jørgensen, L. N. & Ørum, J. E. Pesticide load—A new Danish pesticide risk indicator with multiple applications. *Land Use Policy* **70**, 384–393 (2018).
Saini, R. K., Bagri, L. P. & Bajpai, A. K. in *New Pesticides and Soil Sensors* 519–559 (Elsevier, 2017).
Finger, R., Möhring, N., Dalhaus, T., Böcker, T. (2017). Revisiting pesticide taxation schemes. Ecological Economics 134: 263–266

Example 1: Tangible pesticide risk indicators

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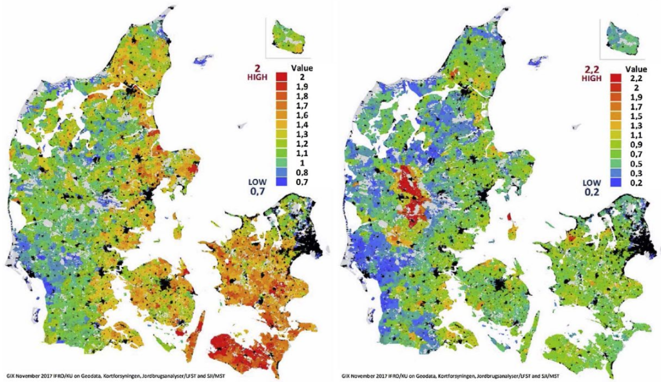
- Purely quantitative indicators (e.g. reduction of tons of pesticide use) alone not necessarily correspond with potential environmental and health risks (Möhring et al., 2019)
- Tangible, transparent risk indicators needed. Transparency also on pesticide use. Denmark serves as possible role model using pesticide load (Kudsk et al., 2019)
- Increasingly better and cheaper, real-time risk-monitoring systems over time and space (Saini et al. 2017)

Pesticide Load Indicator

- **Three sub-indicators**
  - Human health (PL_{HH})
    - Operator exposure (risk phrases on the label)
  - Fate in the environment (PL_{ENV})
    - Persistence, bioacumulation, mobility (data from PPDB)
  - Ecotoxicology (PL_{ECO})
    - Effects on non-target organism (data from PPDB)
- **$PL = PL_{HH} + PL_{ENV} + PL_{ECO}$**



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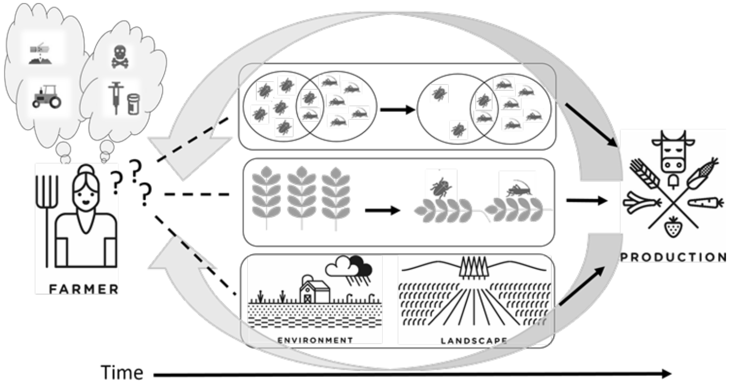
Example 2: Farmer decision-making processes



- Crucial pest management decisions are made at farm level
- More than profit maximization. Uncertainty, risk perception & preferences and further behavioral factors matter (e.g. Dessart et al., 2019, Möhring et al., 2020a,b)
- Effective policies must consider farmers' heterogeneous behavior and decision rationales
- Pesticide taxes, information and extension services. Farmers' self-selection allows to reduce the complexity and specificity and may increase cost-efficiency

Dessart, F. J., Barreiro-Hurlé, J. & van Bavel, R. Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. *Eur. Rev. Agric. Econ.* **46**, 417–471 (2019).
Möhring, N., Bozzola, M., Hirsch, S. & Finger, R. Are pesticides risk decreasing? The relevance of pesticide indicator choice in empirical analysis. *Agric. Econ.* **51**, 429–444 (2020).
Möhring, N., Wüpper, D., Musa, T., Finger, R. (2020). Why farmers deviate from recommended pesticide timing: The role of uncertainty and information. Pest Management Science. In Press
Iyer, P., Bozzola, M., Hirsch, S., Meraner, M., Finger, R. (2020) Measuring Farmer Risk Preferences in Europe: A Systematic Review. Journal of Agricultural Economics. 71(1): 3-26
Böcker, T., Britz, W., Möhring, N., Finger, R. (2020). An economic and environmental assessment of a glyphosate ban for the example of maize production. European Review of Agricultural Economics 47(2), 371-402

Example 3: Smart Farming

- New information communication technology will disrupt agricultural practices to potentially reduce agriculture's ecological footprint (e.g. Walter et al., 2017)

www.ecorobotix.com

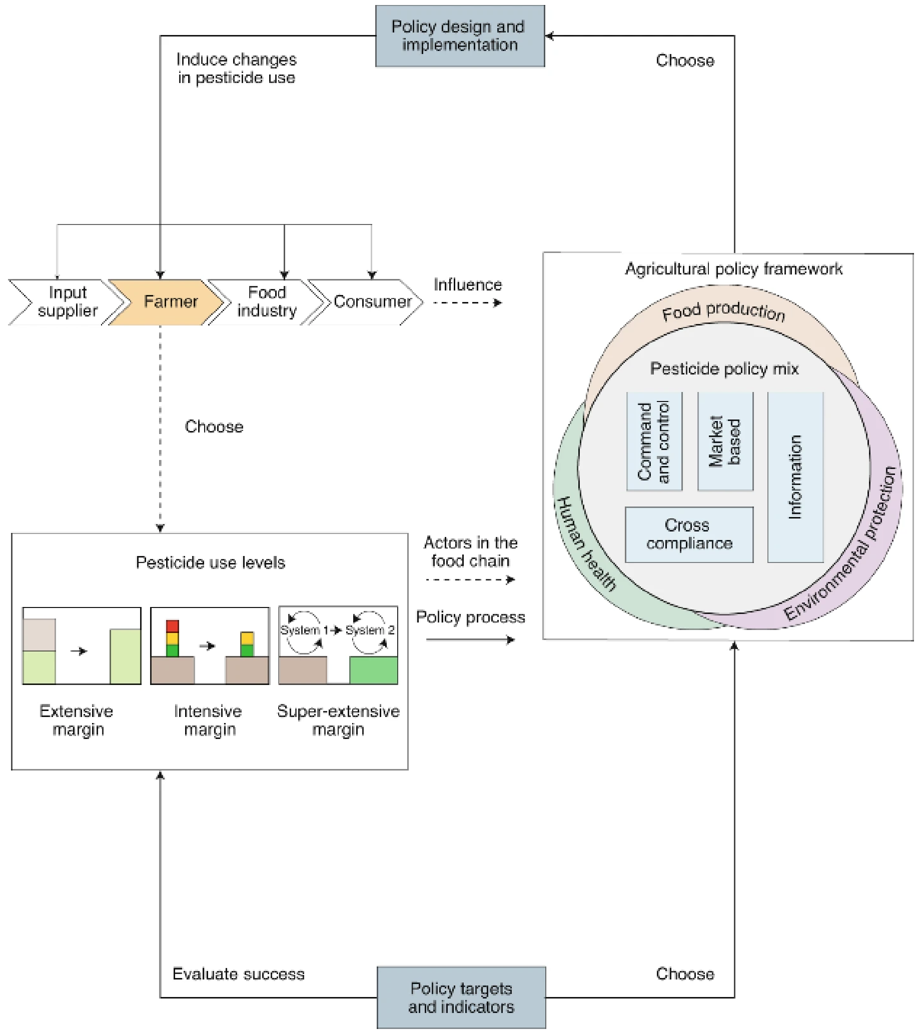
- For example, detection and classification of weeds, pests and diseases; targeted spraying

- Challenges remain: technology; uptake limited to large farms in selected countries (e.g. Finger et al., 2019).

- But: Large-scale, rapid adoption needed to untap potential.This requires push and pull (e.g. infrastructure, legal frameworks, taxes)

Finger, R., Swinton, S., El Benni, N., Walter, A. (2019). Precision Farming at the Nexus of Agricultural Production and the Environment. Annual Review of Resource Economics 11: 313-335
Walter, A., Finger, R., Huber, R., Buchmann, N. (2017). Smart farming is key to developing sustainable agriculture. Proceedings of the National Academy of Sciences USA 114 (24) 6148-6150

A framework for pesticide policies



Policy targets and indicators (bottom) feed into the choice of the pesticide policy mix (right), which has to account for interactions between food production, human health and environmental protection – and is embedded in the agricultural policy framework. Design and implementation of policies are essential for their effects on actors (top) – and ultimately for farmers' choice of pesticide use levels (left). Success of policies may be evaluated along extensive, intensive and super-extensive margins, which refer to changes in pesticide use levels induced by farmers' land use changes, changes in pesticide use intensity (for example, per crop or hectare) and changes in the agricultural system (for example, switch from conventional to organic agriculture), using the defined policy indicators and targets.

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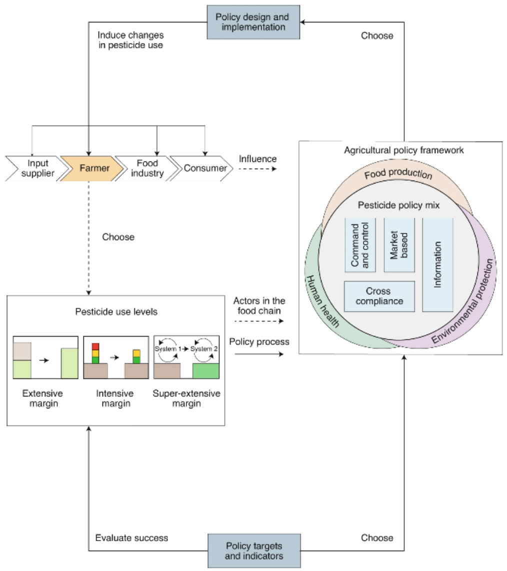
A holistic approach to pesticide policies

- Pesticide policies involve trade-offs and stress-points
  - New technologies can reduce trade-offs but may not be accepted by consumers (and farmers)
- Individual policy goals may contradict each other
  - Bans of single pesticides may, for example, increase long-term gaps in plant protection and lead to more resistances with severe agronomic consequences
- Holistic and simple policy framework and long-term planning horizons needed
- Pesticide policy should be integrated in a holistic food policy framework (e.g. de Schutter et al., 2020, Farm to Fork)
- The political process must be dynamic and policies have to be continuously adapted to fit future changes in agricultural systems



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De Schutter, O., Jacobs, N. & Clément, C. A 'Common Food Policy' for Europe: How governance reforms can spark a shift to healthy diets and sustainable food systems. *Food Policy* https://doi.org/10.1016/j.foodpol.2020.101849 (2020).

Case study: Pesticide free wheat production in Switzerland

Initial situation:

- Successful example of private-public partnership for pesticide-reduced production
  - IP-SUISSE Extenso wheat (only herbicides + seed treatment)
  - Existing since ~30 years
- Farmers receive a price markup (ca. 5 Fr/dt on top of 50 Fr/dt) and a direct payment (400 CHF/ha)
- 50% of Swiss wheat → e.g. TerraSuisse label

Case study: Pesticide free wheat production in Switzerland

Next step:

- IP-SUISSE is currently establishing pesticide-free wheat production program (pilot started 2018/19)
  - Pesticide-free
  - No implication for other crops in crop rotation
  - Not organic

- Migros announced to only sell «pesticide-free» bread from 2023 on
  - Situation 2020: farmers get (additional) price-mark-up (10 Fr/dt) and additional direct payment (250 Fr/ha)

15.06.2020 - MEDIENMITTEILUNGEN

MIGROS SETZT BEI BROT AUS DER JOWA-BÄCKEREI AUF KOMPLETT PESTIZIDFREI ANGEBAUTEN WEIZEN

Zürich - Nach erfolgreichen Tests beginnt die Migros offiziell mit der Umstellung auf komplett pestizidfreien Anbau von Brotgetreide. Die JOWA verarbeitet jährlich 85'000 Tonnen IPSUISSE-Getreide zu Brot und Backwaren für die Migros und verwendet dabei bereits Getreide ohne Fungizide, Insektizide und Halmverkürzer. Neu wird beim Anbau auch auf Herbizide verzichtet. Bis 2023 setzt die Migros nur noch Getreide aus komplett pestizidfreiem Anbau ein.

v.l.n.r. Fritz Rothen, Geschäftsführer IP-SUISSE; Andreas Stalder, Präsident IP-SUISSE; Stefan Gygli, LCM Brot / Feinbackwaren / Convenience; Lorence Weiss, Leiter Direktion Frische; Tobias Eugster, Leiter BU Brot- und Backwaren (JOWA), Hans-Ruedi Christen, Leiter Segment III M-Industrie (JOWA). IP Suisse, Migros und JOWA bauen ihre langjährige Partnerschaft weiter aus.

IP-Suisse Bauer Roland Binder aus Baldingen im Weizenfeld. Dieses Jahr wurden erstmals keine Herbizide eingesetzt. Gleichwohl sind nur wenige Klebern, Kamillen und Blacken zu sehen. (Bild Josef Scherer)

Ackerbau / Erstmals wird dieses Jahr IP-Suisse Getreide geerntet, für das im Anbau auch auf Herbizide verzichtet wurde.

BALDINGEN Schön steht der Weizen, Sorte Nara, bei Roland Binder. Wenig Beikraut ist zu erkennen, einige Klebern, Kamillen, einzelne Blacken. Ende Juli wir er in dieser Höhenlage dreschen können, je nach Wetter. Es ist ein spezielles Brotgetreide: Ressourcenschutz, erreicht bei dieser IP-Suisse Labelanforderung 31.5 Punkte.

Die Chance nutzen

Auch mit IP-Suisse Brotgetreide, gemäss Anfoderungen ohne Fungizide und ohne Insektizide, mit wenig Pilzdruck könne eher von diesen Anbaubedingungen profitieren. So könnten im Schnitt durchaus 60 bis 65 dt pro Are geerntet werden. Die Rechnung gehe also auf. «Wenn der Konsument bereit ist, diese Bemühungen zu honorieren, soll- zwölf Franken Zuschlag eine faire und realistische Abgeltung in Aussicht gestellt wurde. Schliesslich sei dies ein grösseres Risiko, es brauche ein grösseres Wissen, mehr Feldbeobachtung, andere Geräte und mehr Handarbeit.

Betriebsspiegel Zimberi

Name	Roland Binder mit Familie, Betrieb «Zimberi», weil der Betriebsgründer einst Zimmermann war.
Ort	Baldingen AG, Voralpine Hügelzone
LN	36 ha
Betriebszweige	IP-Suisse Betrieb; Obstbau 280 Aren (Kirschen,

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Case study: Pesticide free wheat production in Switzerland

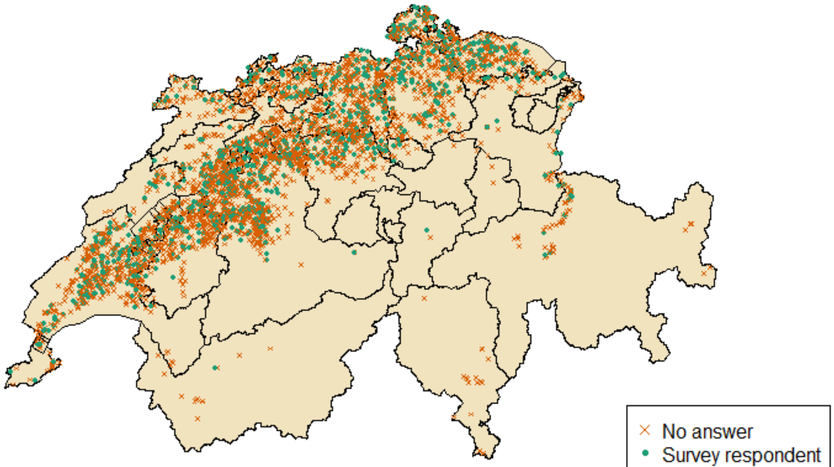
Our Research:

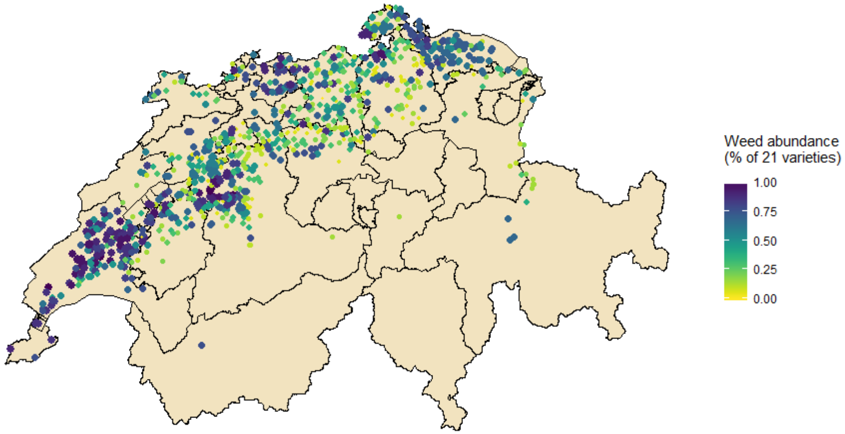
- A) Ex-ante assessment of this step using a bioeconomic model as basis for the decision made by Migros and IP Suisse (Böcker et al., 2019)
- B) Ex-post assessment of the first uptake decisions (Möhring and Finger, in prep.)
  - Goals: identify determinants, challenges and adoption barriers for the uptake of pesticide-free wheat production in Switzerland
  - Large-scale survey focusing on adoption and adoption intention, farm and farmer characteristics, preferences, perceptions and non-cognitive skills

Böcker, T., Möhring, N., Finger, R. (2019). Herbicide free agriculture? A bio-economic modelling application to Swiss wheat production. Agricultural Systems 173, 378-392
Möhring, N., Finger, R. Pesticide-free but not organic? Adoption of a large-scale pesticide-free wheat production standard in Switzerland

Dataset combines various elements

- Survey data (all IP Suisse wheat producers, 1105 returned surveys, ca. 25%)
- Structural farm data [IP-SUISSE]
- Delivered Extenso yields (dt/ha) of last 10 years [IP-Suisse]
- Weather and climate data (farm-level) [MeteoSwiss]
- Weed pressure/abundance (municipality level) [InfoFlora]
- Herbicide resistances (municipality level) [Agroscope
- Soil suitability (farm-level) [BLW]





Survey structure

- Participation and program expectations
  - (potential) participation IP-Suisse + direct payment programs for «resource efficiency»
  - Importance of selected benefits and costs of adoption
  - (Expected) herbicide substitution strategies and availability
  - (Expected) changes in yield and production risk
- Farm and farmers’ characteristics
- Behavioral characteristics
  - Risk preferences
  - Expected environmental and health benefits of the program
  - Environmental Attitudes
  - Farming objectives
  - Self-efficacy
  - Locus of control

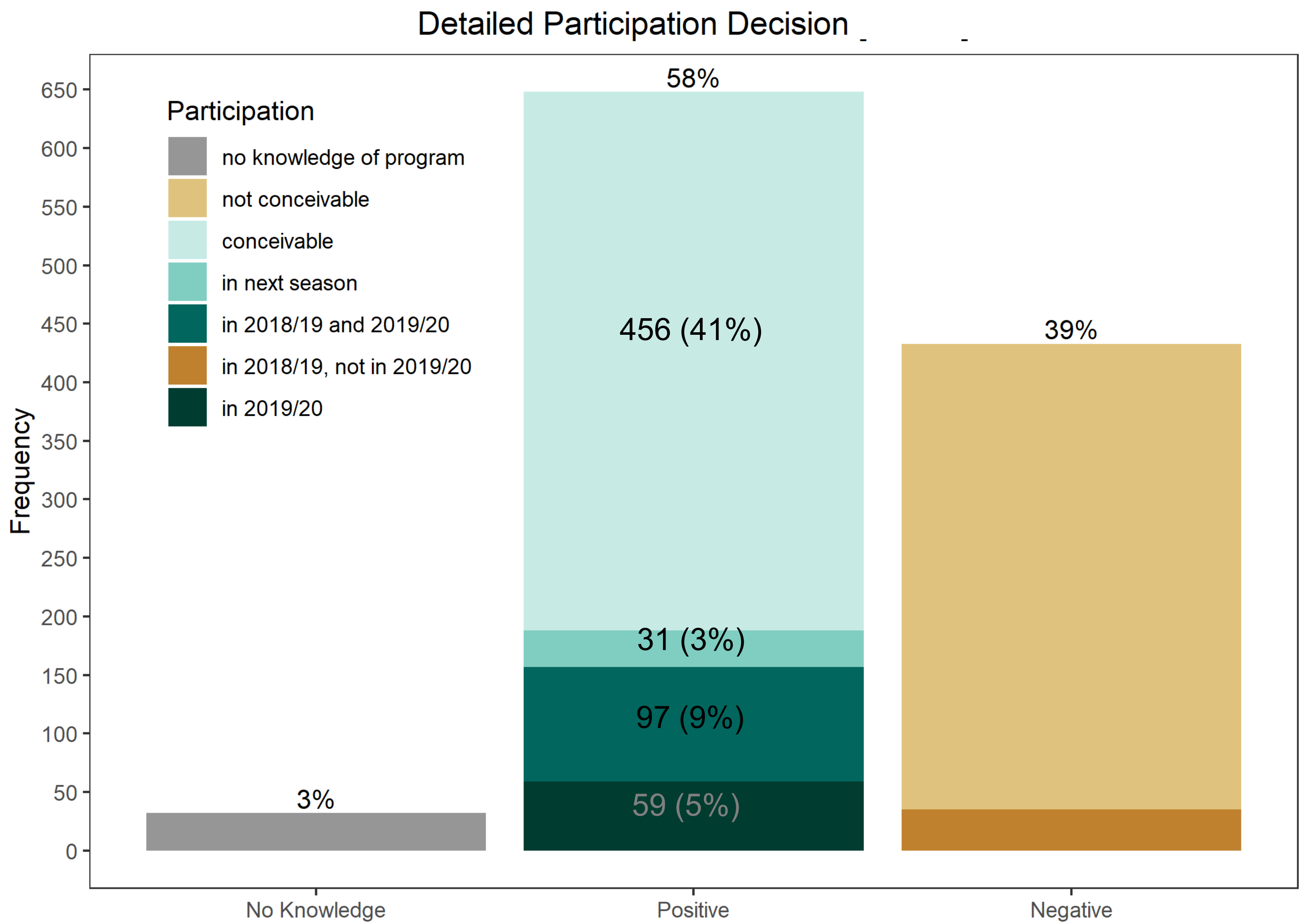
Econometric analysis

- Explain adoption or planned adoption using a wide set of explantory variables representing
  - Production system before adoption
  - Farm, farmer and environmental conditions
  - Farmers' perceptions and expectations
  - Adjustment costs

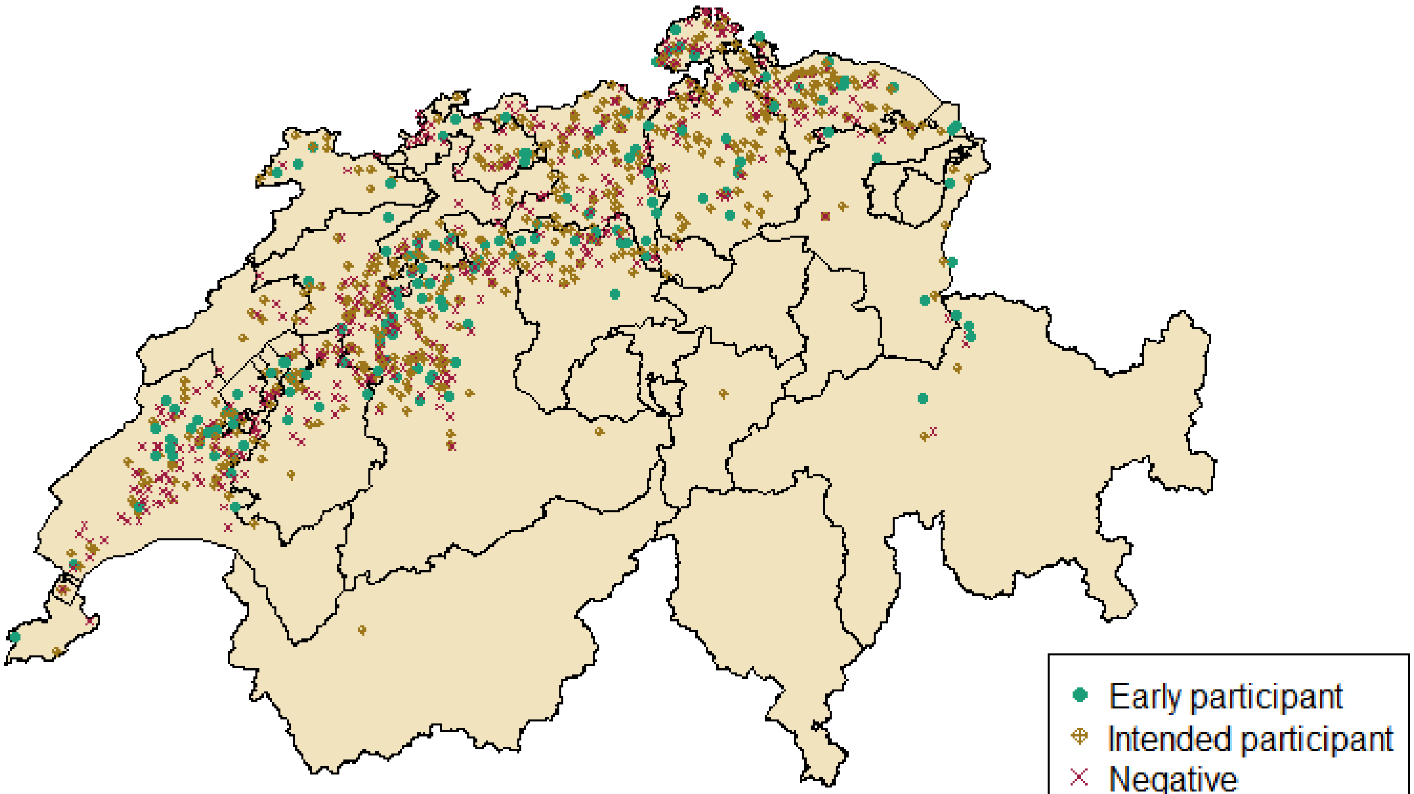
- Estimation via OLS, clustering at cantonal levels

- Various robustness checks, for example
  - Inclusion of different sets of explanatory variables
  - Wild bootstrap approach to address issue of heterogeneity of clusters (cantons)
  - Split samples, e.g. in early adopters and intended adopters
  - Address potential impact of selection on observable and unobservables using Oster Bounds

Descriptive results: participation decision (N=1105)



Participation decision: spatial distribution (N=1105)



Preliminary results

- Adoption is mainly driven by farmers` expectation of the program
  - (+) perception of positive environmental effects of pesticide free production
  - (-) expectations of higher yield loss or higher production risks
  - (-) higher investment risks in machinery (i.e. for mechanical weed control)
  - (-) higher risk aversion

- Prior farming system and adjustment costs matter:
  - (-) engagement in soil conservation programs or in cantonal programs for pesticide use reduction
  - (-) lack of machinery for mechanical weed control

- No effects of structural farm and farmers' characteristics, as well as environmental conditions
  - Also farmers' expectations regarding possible positive health effects are not significant

- Robustness checks confirm main results. Early adopters on average perceive risks as lower, have prior experiences and no commitment in other programs, are in Western Switzerland

Conclusion

- Reduction of pesticide risks for human health and the environment is a key policy (and industry) goal

- Holistic approach for pesticide policies needed that spans across various actors along the value chain. Long-term planning horizons needed. New production systems need to be combined with new technologies

- Many good examples on the way. Example pesticide free wheat production in Switzerland
  - bringing together public policy measures & market incentives,
  - accounts for consumer and farmers decision making; creates new production systems
  - ongoing research on how smart farming (e.g. remote sensed weed scouting) can support this pesticide free production

ETH zürich

Thank you very much for your attention

www.aecp.ethz.ch

https://agrarpolitik-blog.com/

Barrier	Positive	Negative
Weed pressure wheat	3.7	4.2
Weed pressure rotation	3.3	4.1
Resistant weeds	3.7	4
Workload	3.3	3.8
Machinery	3.4	3.7
Incompatible soil	2.6	3.1
Missing experience	2.8	2.4
Swapping fields	1.6	1.7
Lower yields	2.9	3.3
Higher risks	3	3.5

- **Figure 2.** Rating of potential adoption barriers by survey respondents
- The heat map shows average rating of the potential adoption barriers by producers in the survey (N = 1073) from 1 (no barrier) to 5 (very strong barrier). “Positive” and “Negative” show groups of producers, which indicated a positive or a negative attitude towards program participation in the survey, respectively.

Adopt	Coefficient (standard error)	
Soil conservation	-0.0972**	(0.0369)
DP_canton	-0.0851*	(0.0415)
Avg_yield	-0.0015	(0.0023)
Canton_fr	0.0286	(0.0318)
Ag_land	-0.0002	(0.0007)
Share_Wheat	-0.0082	(0.1401)
Workforce	-0.0027	(0.0105)
Income_arable	0.0000	(0.0006)
Succession	-0.0146	(0.0297)
Share_mountain	-0.0487	(0.0431)
Suitability_grains	-0.0268	(0.0203)
Temperature	-0.0223	(0.0284)
Precipitation	0.0002	(0.0003)
Weed	0.0004	(0.0445)
Herbicide_resistance	-0.0756	(0.0687)
Age	-0.0022	(0.0018)
Education	-0.0259	(0.0278)
Exp_yield_decr		
1	0.0022	(0.0522)
2	0.1761**	(0.0626)
3	0.1261**	(0.0563)
4	0.1111*	(0.0536)
Exp_yield_risk	-0.1049***	(0.0281)
Risk_pref	0.0178***	(0.0046)
Pos_Environ	0.0994***	(0.0155)
Pos_Health	-0.0029	(0.0112)
Experience		
1	-0.0344	(0.0281)
2	-0.0289	(0.0236)
Availability_machinery	0.1409***	(0.0426)
Exp_risk_machinery	-0.0342***	(0.0116)
Exp_costs	-0.0002	(0.0002)
Constant	0.7921*	(0.3888)

Table 4. Regression results main model

Internal validity checks

Mean Variables	Participants	Population	Difference (%)
First year Extenso	2004	2005	0
Wheat surface (ha)	5.68	4.78	0.19
Share wheat (%)	0.16	0.15	0.1
Agricultural land (ha)	34.49	32.39	0.06
Animal stock (GVE)	31.24	31.12	0
Share mountain zones (%)	0.05	0.07	-0.25
Temperature (°C)	9.01	8.96	0.01
Precipitation (mm)	1077	1093	-0.01
Delivered quantity (dt/ha)	51.13	50.7	0.01
SD delivered quantity	13.33	13.09	0.02
Suitability grain (%)	0.81	0.76	0.06

- Participants represent population very well overall
- Particpants: slightly larger farms with more wheat, less mountain regions
- If any – positive “production“ bias
- No obvious spatial misrepresentation (map)