Pre-Registration Plan: Influence of Network Exposure and Spillover Effects on Adoption Rate of Plant Food Production

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1. Abstract

This study examines how peer network exposure shapes farmers' decisions to adopt plant food production, and whether spillover effects emerge among untreated farmers. Despite growing policy interest in diversification away from livestock, the role of social network exposure in such transitions remains empirically underresearched. The study is embedded in a multi-wave randomized controlled trial (2026–2028) with three arms in the Canton of Lucerne (advisory only, advisory plus a CHF 10,000 experimental budget, internal control) and an external control group in Cantons Aargau, Thurgau, and St. Gallen. Farm-level outcomes are measured through both stated survey-based change figures and revealed behavioural outcomes from farm census data.

Keywords: Plant food production, network exposure, spillover effects, randomised control trial, production type switching

2. General Information

2.1 Background

Agri-food system transformation toward more sustainable and resilient production and consumption is essential for climate, environmental, and public health targets(Willett et al., 2019), with livestock production being a major driver of greenhouse gas emissions, nutrient imbalances, and land use pressure (Grossi et al., 2019). A transition from livestock to more plant food production is needed but remains slow globally and in Switzerland (Djanibekov et al., 2026; Müller et al., 2025). Policy instruments play an important role in supporting this transition (Fesenfeld et al., 2023), yet the causal effectiveness of measures promoting production type shifts to more plant-rich food has not been tested experimentally in the Swiss and European context.

To design effective and feasible policy instruments, it is necessary to understand what determines whether and how farmers make this shift. For individual farmers, production types have substantial implications, affecting livelihoods, land use, and established production systems (Meraner & Finger, 2019). While agronomic and economic conditions are important, considering behavioural factors enriches analyses of farmer decision-making and leads to more feasible and effective agri-environmental policy (Dessart et al., 2019).

Farmers do not make this decision in isolation; they learn from, imitate, and are influenced by geographic and social neighbours (Conley & Udry, 2010; Krishnan & Patnam, 2014). Understanding production-type shifts therefore requires situating the decision within a farmer's network context, since networks shape an individual's likelihood of transition and can carry the effects of a policy intervention beyond those directly targeted.

Exposure within a farmer's personal network shapes adoption decisions. Unlike simple information diffusion, behavioural change often requires social reinforcement (Centola, 2010; Valente, 1996). This reinforcement is not evenly distributed, as farmers learn preferentially from peers with a similar production orientation (homophily; (Jackson, 2014)), so the strength of the effect depends on the type of contacts who adopted, not only their number.

Because networks can both sustain established practices and transmit change once it occurs, treatment effects are not necessarily confined to treated farmers. Farmers' social networks generate regional spillovers in related agricultural behaviour change (Kreft et al., 2023). Geographic proximity and tie intensity contribute to the diffusion of sustainable practices to untreated farms (Vroege et al., 2020; Wang et al., 2023), though proximity alone is not sufficient, as effects are only robust once the strength of the underlying social tie is accounted for (Wang et al., 2023).

2.2 Main Research Questions

- **RQ1:** Do treatment effects extend to other treated and untreated farmers (i.e., spillover effects) over time?
- **RQ2:** Does the network exposure of farms with plant food production in the network of treated farmers moderate the magnitude of intended, reported and revealed plant food production?

2.3 Hypotheses

Based on review of the existing literature, we formulated the following testable hypotheses on the direct and indirect effects of the treatment on farmers' behaviour change.

Spillover effects

- **H1a:** Treated farmers have a higher intensity of exchange with other treated farmers compared to untreated farmers.
- **H1b:** Farmers that have a higher share of treated farmers in their network, are more likely to intend, report and reveal a change over time in their plant food production compared to farmers with a lower or no share of treated farmers in their network.
- **H1c:** Farmers that have a higher share of treated farmers in their geographic proximity are more likely to intend, report and reveal a change over time in their plant food production compared to farmers with a lower or no share of treated farmers in their geographic proximity.

- **H1d:** Farmers that have higher share of shared association memberships as treated farmers are more likely to intend, report and reveal a change over time in their plant food production compared to farmers who have a lower or no share of shared association memberships as treated farmers.
- **H1e (descriptive):** Untreated farmers that have a higher share of treated farmers in their network are more likely to intend, report and reveal a change in their plant food production compared to untreated farmers with a lower or no share of treated farmers in their network.
- **H1f (descriptive):** Untreated farmers that have a higher share of treated farmers in their geographic proximity are more likely to intend, report and reveal a change in their plant food production compared to untreated farmers with a lower or no share of treated farmers in their geographic proximity.
- **H1g (descriptive):** Untreated farmers that have a higher share of shared association memberships as treated farmers are more likely to intend, report and reveal a change in their plant food production compared to untreated farmers who have a lower or no share of shared association memberships as treated farmers.

Network Exposure effect

- **H2:** The treatment effect is moderated by pre-treatment network exposure, such that treated farmers are more likely to increase their plant food production compared to the control group if before the treatment start they have had a larger network exposure to farmers who engage in plant food production.

3 Interventions

3 Experimental Details

3.1 Experimental Design

The study follows all four arms across three data-collection waves over approximately three years (baseline September–October 2026, Year 1 November 2027, Year 2 November 2028), with an optional Year 3 wave in November 2029 pending a decision on study extension.

Farm-level survey data are linked to farm census data via farm identification number across all waves, allowing comparison of stated (survey) and revealed (census) preferences. We recruit from Canton Lucerne as the treatment region and from Cantons Aargau, Thurgau, and St. Gallen as an external control region with comparable farm structural characteristics. Within both regions, farms are eligible if they are located in the respective recruitment region, are eligible for Swiss direct payments, and operate animal production at the time of recruitment (standard livestock unit > 0). Contact data for outreach is provided by the Federal Office for Agriculture (BLW); farms already at the BLW's cap on survey invitations in the current calendar year cannot be proactively invited but remain eligible and may register by contacting the project team directly; eligible farms are then granted access to the survey. Eligible farms with available contact data are invited near-exhaustively within each region. The study deliberately targets farms that have not already fully committed to plant food production; subject to sufficient overall sample size, the analysis may exclude farms for which plant food production already constitutes 91–100% of agricultural income at baseline, and farms that indicate at baseline they would not accept either treatment if assigned, with such restrictions pre-registered and applied only if they do not compromise statistical power. Eligible farms receive a written invitation letter and follow-up email, with a reminder letter and email sent to non-respondents two weeks later, and two information events (in-person and hybrid) before registration closes at the end of October 2026. Farms are informed of their arm assignment by letter post and email in early December 2026; farms assigned to Arms 1 and 2 must actively confirm participation via a confirmation link. Replacement farms are recruited from the pool of registered control farms with similar characteristics on pre-specified balancing variables where withdrawals or non-confirmations occur.

Randomization Method

Following completion of survey registration, eligible farms in Canton Lucerne will be randomly assigned to the three study arms: 75 farms to Arm 1, 50 to Arm 2, and the remaining eligible farms to Arm 3. Farms in the external control cantons (Aargau, Thurgau, and St. Gallen) will be assigned directly to Arm 4 and will not enter this randomization procedure.

We will use rerandomization to improve covariate balance. Candidate allocations will be generated by computer and evaluated using Mahalanobis distance across a set of covariates grouped into priority tiers, including baseline outcomes, geographic characteristics, and other farm-level characteristics. Balance thresholds for each tier will be calibrated beforehand using simulated allocations and fixed prior to the final randomization.

For the final randomization, a new and independent set of allocations will be generated by computer, and the allocation ultimately used will be drawn uniformly at random from those satisfying all balance criteria. Randomization will take place after survey registration closes but before treatment delivery and before any post-treatment outcomes are observed.

3.2 Interventions

Farms within Canton Lucerne are randomly assigned to one of three arms — two treatment arms (advisory services (Arm 1); advisory services plus an experimental budget (Arm 2)) and an internal control (Arm 3); farms in the external control cantons (Aargau, Thurgau, and St. Gallen) are assigned directly to the external control (Arm 4), without random assignment among themselves.

- **Arm 1 — Advisory services (n≈75)**: Farms first receive an initial advisory session: a three-hour on-site consultation conducting a location and potential analysis with the farm operator, enabling an informed choice of a subsequent tailored advisory track: (1) specialty crops or specialty arable farming, (2) Agri-PV combined with specialty crops, (3) regenerative plant food production, (4) agroforestry, or (5) a voucher for an equivalent advisory service of the farm's own choice. Tailored advisory is delivered by regional public advisory services and specialised consultancies.

- **Arm 2 — Advisory services plus experimental budget (n≈50)**: Farms receive the same initial and tailored advisory as Arm 1, plus a one-time unconditional cash payment of CHF 10,000, disbursed in July 2027 via the cantonal agricultural authority, conditional on completion of the initial advisory session. The same fixed sum is paid to every Arm 2 farm irrespective of farm size. Prior to disbursement, Arm 2 farms submit a non-binding intention document describing their planned use of the budget; no repayment obligation applies if a farm subsequently withdraws or uses the funds differently than stated.
- **Arm 3 — Internal control (n≈300–600)**: Located within the treatment region (Canton Lucerne); receives no treatment; participates in all three survey waves and provides farm census data access.
- **Arm 4 — External control (n≈300–600)**: Located in Cantons Aargau, Thurgau, and St. Gallen; receives no treatment; same survey and census participation as Arm 3.

Both control groups (Arms 3 and 4) are jointly eligible for a prize draw after each survey wave (20 farms, CHF 500 each, drawn from both groups combined), as compensation for survey participation rather than a treatment component.

3.3 Variables of Analysis

Primary Outcomes (Baseline, Year 1, Year 2)

- Overall plant food production change: 7-point Likert item, retrospective 5-year (baseline wave only) and prospective 12-month and 5-year (all waves)
- Area, tree count, and livestock-unit (GVE) change:
    - retrospective (baseline only) — a single item (Δ ares, agricultural land for human food production)
    - prospective (all waves) — a full multi-category battery in all waves, covering agricultural land for human food production, agricultural land for feed production, specialty crops excluding vineyards, vineyards, greenhouse production, and tree count (all in ares or count), plus livestock units by category (cattle, pigs, poultry, sheep/goats, other) in GVE

Moderating Variables

- **Network Exposure (pre-treatment baseline)**
    - **Primary specification:**

      (1) $NE_i^{primary} = \frac{A_i}{B_i}$

      Where A_i = N(contacts who have expanded plant food production, excluding feed), and B_i = N(total contacts with whom the farmer exchanged about plant food production, excluding feed)
    - **Alternative specifications:**
        - Weighted by raw adopter count:

$$(2)\ NE_i^{alt1} = \frac{A_i}{B_i} \times A_i = \frac{A_i^2}{B_i}$$

As an alternative to the primary exposure ratio, we test a specification that additionally weights exposure by the absolute number of contacts who expanded their plant food production (B_i). Under the ratio alone, a farmer with one contact who adopted ($NE = 1.0$) scores higher than a farmer with ten contacts, four of whom adopted ($NE = 0.4$), despite the latter having more farmers in absolute terms in their network who expanded their plant food production. The alternative specification accounts for this by scaling the ratio by the raw adopter count.

- Weighted by intensity of interaction:

$$(3)\ NE_i^{alt2} = \frac{A_i}{B_i} \times I_i$$

where I_i= mean interaction intensity (7-point Likert, "not at all intense" to "very intense") across the farmer's exchange contacts.

As a second alternative to the primary exposure ratio, we test a specification that weights exposure by the intensity of interaction with adopting contacts, on the grounds that not all exchange relationships carry equal informational or normative weight. A high exposure ratio driven by superficial contact plausibly has less influence on the farmer's own decision-making than the same ratio sustained through frequent, in-depth exchange.

- **Spillover:**
  - **Geographical Proximity (baseline):** farm's own canton (Lucerne / external canton) * majority contact location (neighbourhood / within canton / external canton)
  - **Membership Association (baseline):** none / Lucerne farmers Association / IP Suisse / Bio Suisse / Sector/professional association / other

Mediating Variables:

Spillover effects:

- **Intensity of Interaction (Y1, Y2):** self-reported exchange intensity (Likert scale) with contacts identified as advisory- or experimental-budget recipients under MehrWert | Pflanzen.

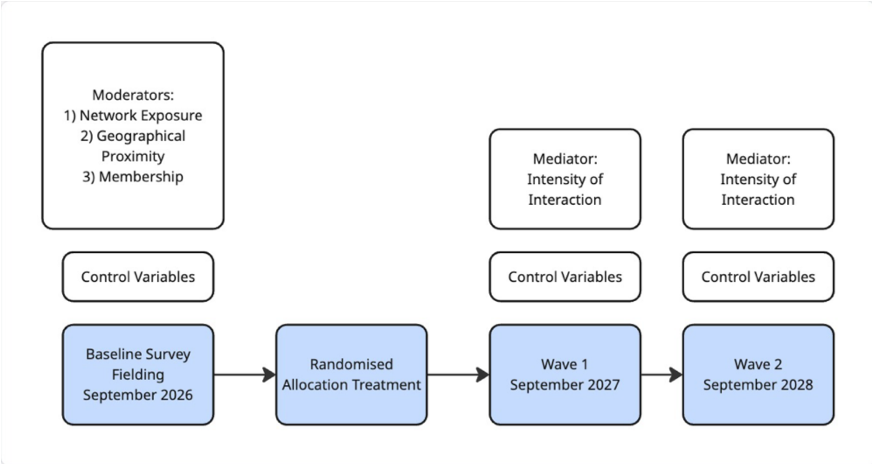

Figure 1: Timeline of data collection, showing when pre-treatment and post-treatment measures were gathered. For further information on data collection timeline see section 3.4.

3.4 Sampling Strategy:

The target sample across all arms is approximately 725-925 farms (Arm 1 n ≈75; Arm 2 n≈50; Arm 3 n≈300–600; Arm 4 n≈300–600).

Region Selection

We recruit from Canton Lucerne as the treatment region and Cantons Aargau, Thurgau, and St. Gallen as the external control region:

- **Canton Lucerne** (Arms 1–3, n≈425–725 combined): Selected as the treatment region for its high livestock density among Swiss cantons and the potential for expanding plant food production and value creation identified by cantonal agricultural and climate strategies.
- **Cantons Aargau, Thurgau, and St. Gallen** (Arm 4, n≈300–600): Selected as an external control region with comparable farm structural characteristics to Canton Lucerne, allowing estimation of treatment effects net of region-specific trends not captured by the internal control alone.

Farm-level Eligibility:

Within both regions, farms are eligible if they (1) are located in the respective recruitment region, (2) are eligible for Swiss direct payments, and (3) operate animal production at the time of recruitment (GVE > 0). Contact data for outreach is provided by the Federal Office for Agriculture (BLW); farms that have already received two other BLW-mediated survey invitations in the current calendar year are not included in this contact data and therefore cannot be proactively invited, though such farms remain eligible and may still register if they learn of the study through other means (e.g., word of mouth, information events, website). Eligible farms for which we hold contact data are invited near-exhaustively within each region rather than sampled via quotas, since the target population is the full set of eligible livestock and mixed farms in each region rather than a broader population requiring demographic stratification.

The study deliberately targets farms that have not already fully committed to plant food production, since the intervention is designed to support farms at an earlier stage of the decision-making process. Subject to sufficient overall sample size, the analysis may exclude farms for which plant food production already constitutes 91–100% of agricultural income at baseline, as these farms have effectively completed the transition the intervention is designed to facilitate, and farms that indicate at baseline they would not accept either treatment if assigned. The decision to apply such restrictions is conditional on a sufficient overall sample size such that exclusion does not compromise statistical power.

Recruitment Procedure:

Eligible farms receive a written invitation letter and follow-up email describing the study, with a reminder letter and email sent to non-respondents two weeks later. Two information events (in-person and hybrid) are held to present the study and answer questions before registration closes. Farms are informed of their arm assignment by email; farms assigned to Arms 1 and 2 are additionally required to actively confirm their definitive participation via a confirmation link. Should withdrawals or non-confirmations occur, replacement farms are recruited from the pool of registered control farms with similar characteristics on the pre-specified balancing variables.

Data Collection Timeline

Data collection will occur via Qualtrics.

- Invitation letters and emails: September 2026.
- Information events: October 2026.
- Registration and baseline survey: closes end of October 2026 (baseline survey completion is part of registration).
- Arm assignment notification: early December 2026.
- Year 1 survey: November 2027.
- Year 2 survey: November 2028.
- Optional Year 3 wave: November 2029, pending decision on study extension.

4 Analysis Plan

To perform the analysis, we will use the statistical software R. To test H1a we will estimate an ANCOVA model. The mediator *interaction intensity* is denoted by δ_{it}. The two treatment conditions are denoted as $Advisory_i$ and $Budget_i$ in the model. Where $Advisory_i = 1$ for farms receiving advisory services only (Arm 1), 0 otherwise; $Budget_i$ = for farms receiving advisory services plus the one-time budget payment (Arm 2). If statistical power does not allow for a separate estimation of the two treatment conditions, we will pool both and denote the pooled treatment as $pooledTreatment_i = 1$ for farms receiving either advisory services only (Arm 1) or advisory services plus the one-time budget payment (Arm 2), 0 otherwise.

- **ANCOVA:**

$$\delta_{it} = \beta_0 + \beta_1 \cdot Advisory_i + \beta_2 \cdot Budget_i + \varepsilon_i$$

To test H1b, H1c, H1d, H2 we will estimate ANCOVA models and in addition for H1c, H1d, H2 also panel fixed-effects regressions. For simplicity we will denote the respective moderators as $M_{i,bs}$ and the respective dependent variable by Y_i. For H1b $M_{i,bs}$ is the *network exposure,* for H1c the *geographic proximity,* and for H1d the *association membership.*

The two treatment conditions are denoted as $Advisory_i$ and $Budget_i$ in the model. Where $Advisory_i$ = 1 for farms receiving advisory services only (Arm 1), 0 otherwise; $Budget_i$ = for farms receiving advisory services plus the one-time budget payment (Arm 2). If statistical power does not allow for a separate estimation of the two treatment conditions, we will pool both and denote the pooled treatment as $pooledTreatment_i$ = 1 for farms receiving either advisory services only (Arm 1) or advisory services plus the one-time budget payment (Arm 2), 0 otherwise.

- **ANCOVA (excl. controls variables):**

H1b/H1c/H1d/H2: $Y_i = \beta_0 + \beta_1 * Advisory_i + \beta_2 * Budget_i + \beta_3 * M_{i,bs} + \beta_4\left(Advisory_i * M_{i,bs}\right) + \beta_5\left(Budget_i * M_{i,bs}\right) + \beta_7 * Y_{i,bs} + \varepsilon_i$

- **Fixed Panel effects regression (excl. controls variables):**

H1c/H1d/H2: $Y_{it} = \alpha_i + \beta_1 * Advisory_{it} + \beta_2 * Budget_{it} + \beta_3(Advisory_{it} * M) + \beta_4\left(Budget_{it} * M_{i,bs}\right) + w_t + \varepsilon_i$

Where α_i are farm fixed effects and w_t are time fixed effects.

As a robustness check, we may include LASSO-based approaches to detect potential omitted interaction bias.

To test H1e, H1f, H1g we will estimate ANCOVA models. For simplicity we will denote the respective moderators as $M_{i,bs}$ and the respective dependent variable is denoted by Y_i. For H1e $M_{i,bs}$ is the *network exposure,* for H1f the *geographic proximity,* and for H1g the *association membership.*

- **ANCOVA (excl. controls variables):**

$$Y_i = \beta_0 + \beta_1 * M_{i,bs} + \beta_2 * Y_{i,bs} + \varepsilon_i$$

Robustness Checks:

All models are re-estimated with time-varying controls: farm census data (direct-payment programme participation), Agridea Richtpreise (reference producer prices) by crop, and wave-varying sociodemographic characteristics. Where external weather and yield-shock data can be sourced and merged by region and year, these will be added as an additional check.

ANCOVA (incl. control variables):

- **H1a:** $\delta_{it} = \beta_0 + \beta_1 \cdot Advisory_i + \beta_2 \cdot Budget_i + \gamma * control\ vars_{it} + \varepsilon_i$
- **H1b/H1c/H1d/H2**: $Y_i = \beta_0 + \beta_1 * Advisory_i + \beta_2 * Budget_i + \beta_3 * M_{i,bs} + \beta_4(Advisory_i * M_{i,bs}) + \beta_5(Budget_i * M_{i,bs}) + \beta_7 * Y_{i,bs} + \gamma * control\ vars_{it} + \varepsilon_i$
- **H1e/H1f/H1g:** $Y_i = \beta_0 + \beta_1 * Control_i + \beta_2 * M_{i,bs} + \beta_7 * Y_{i,bs} + \gamma * control\ vars_{it} + \varepsilon_i$

As an additional robustness check and potential mediation analysis we will re-estimate the models for H1b, H1c, H1d, H2 while including the interaction intensity as a mediating variable.

- $Y_i = \beta_0 + \beta_1 * Advisory_i + \beta_2 * Budget_i + \beta_3 * M_{i,bs} + \beta_4(Advisory_i * M_{i,bs}) + \beta_5(Budget_i * M_{i,bs}) + \beta_6 * \delta_{it} + \beta_7 * Y_{i,bs} + \gamma * control\ vars_{it} + \varepsilon_i$

Fixed Panel effects (incl. control variables):

- **H1c/H1d/H2:** $Y_{it} = \alpha_i + \beta_1 * Advisory_{it} + \beta_2 * Budget_{it} + \beta_3(Advisory_{it} * M_{i,bs}) + \beta_4(Budget_{it} * M_{i,bs}) + w_t + \gamma * control\ vars_{it} + \varepsilon_i$

Randomization inference considering rerandomization:

Because treatment assignment relies on a rerandomization procedure, which restricts treatment allocation only to treatment assignments with an acceptable covariate balance, we will account for this restricted randomization when conducting inference. For that, we will use all treatment allocations in the acceptance region generated during the final rerandomization procedure, including the final allocation used in the experiment, to construct the randomization distribution for hypothesis testing (Morgan & Rubin, 2012; Zhang & Zhao, 2023).

Specifically, under the sharp null hypothesis of no treatment effect, we hold the observed outcomes of each farm fixed and re-estimate the relevant treatment-effect statistic for each acceptable treatment allocation from the acceptance region obtained via the rerandomization procedure (Morgan & Rubin, 2012). For each acceptable allocation, we calculate the same treatment-effect statistic as in the corresponding analysis specification, such as the treatment coefficient in the pooled specification or the difference between arm-specific coefficients in the arm comparison specification (see below). We then obtain a randomization distribution of the treatment-effect statistic under the sharp null. The p-value is subsequently calculated as the proportion of acceptable allocations for which the treatment-effect statistic is at least as extreme as the statistic from the actual arms allocation.

We will generate at least 1,000 acceptable allocations during the rerandomization procedure for these to be used in the randomization test; increasing the number of simulated allocations increases the accuracy of the resulting p-value. Given our three-arm design, we will apply the procedure pairwise to Arm 1 versus Arm2, Arm 2 versus Arm 3, and Arm 1 versus Arm 3. According to Morgan and Rubin (2012), such a randomization test works regardless of the rerandomization procedure, preserves the significance level of the test (Moulton, 2004), and can be applied to any estimator. In our case, we apply it to the treatment-effect statistics from our ANCOVA and panel fixed-effects specifications.

Outlier Treatment:

We will apply a multivariate outlier identification procedure (e.g. Billor et al. (2000)) to identify outlying observations (dependent and potential control variables). In addition, we eliminate observations in the prior and posterior elicitation to capture observations that have been answered in an unserious manner (e.g. where the questions have been obviously misread or answered in an obvious unserious manner). Implausible observations will also be removed.

5. Ethics and Consent

All respondents provide informed consent before participation. The survey presents no risk. Respondents are informed that participation is voluntary and they may withdraw at any time. No personally identifiable information beyond basic demographics is collected. The study has been reviewed and approved by ETH Zurich's Ethics Board (approved project 26 ETHICS-249).

6. Sponsors and Partners

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