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# Sustainable Soil, Sustainable Specialty Crops Production: How Soil Liming Impacts Profits and Rotations

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Soil acidity poses a significant challenge for growers across Western Canada. Many specialty crops, such as pulses, are highly sensitive to soil pH—a measure of acidity—which must be maintained within a narrow optimal range to support healthy plant growth. Soil liming is an effective agricultural management practice to mitigate soil acidity. By increasing soil pH, liming enhances nutrient uptake, improves soil structure, and supports healthy plant development (Enesi et al., 2023).

Despite its clear agronomic benefits, the adoption of soil liming remains surprisingly low. The two maps in Figures 1 and 2 tell a striking story. Figure 1 shows widespread soil acidification across Canada, particularly in eastern regions and parts of Alberta. These areas have pH levels well below the optimal range, typically between 6.0 and 7.0, for pH-sensitive specialty crops like chickpeas.

The second map shows the proportion of farmland where lime is applied. This suggests that adoption remains extremely low, with most areas reporting lime use on less than 1% of farmland. Together, the maps highlight a concerning gap: while soil acidification affects millions of hectares, the practice of applying lime to neutralize acidity remains rare. This gap raises concerns about long-term soil health, crop yields, and the sustainability of Canadian agriculture.

So why is adoption so low? One likely factor is economic uncertainty. Many farmers are hesitant to invest in lime due to concerns about cost-effectiveness. Short-term studies show mixed results. For example, Haak (1990) reports that the initial yield increases from liming were insufficient to offset the input costs, leading to net revenue losses. In contrast, Bongiovanni and Lowenberg-DeBoer (2000) find that using lower lime rates can be economically viable in the short term. For medium-term outcomes, research by Liu, Conyers, and Helyar (2003) estimates that for a 10-year crop rotation, the cost-effective lime application rate ranges from 2.0 to 5.5 tonnes per hectare.

What about the long-term effects on yield? Li et al. (2010) find that wheat and canola yields can double after three rotations, increasing gross margins by as much as 25%. The very long-term outlook appears even more promising. Research by Malhi et al. (1995), as well as Warner et al. (2023), shows that a single application of lime can boost yields for 16–27 years. However, Holland and Behrendt (2021) caution that significant positive returns may take 2 decades to become evident.

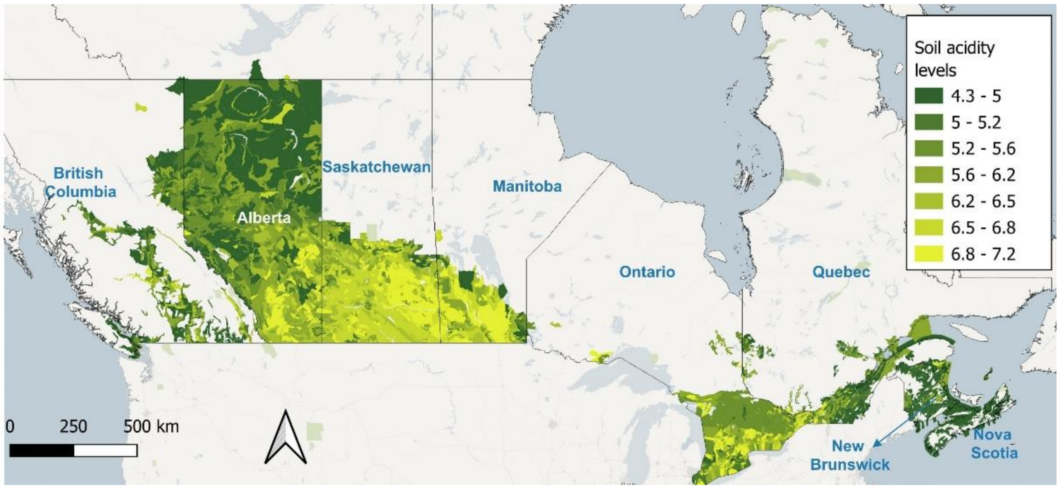
The aforementioned studies provided valuable insights into the cost-effectiveness of liming in both the short term and long term. However, these studies primarily focused on yield effects and overlooked a key driver of farm profitability: crop rotation strategies. By improving soil pH over time, liming not only increases yields but also broadens the range of crops that can be grown, especially high-value specialty crops that thrive in near-neutral pH conditions. Without liming, natural soil acidification may push farmers toward more acid-tolerant crops like wheat, limiting flexibility and long-term profitability.

Our analysis sheds light on how liming affects crop rotation systems, helping to explain why the gap between short- and long-term profitability leads to the persistently low adoption of liming among Canadian growers. Healthy soil delivers more than just biological benefits; it yields clear economic returns. Yet farmers are often forced to balance immediate costs against uncertain long-term gains. Despite the evident economic benefits, many farmers hesitate to invest in liming. The upfront costs and site-specific conditions, combined with uncertain returns, often make liming a hard sell.

## Economic Model: How We Ran the Numbers

At the heart of this study is a detailed economic model that simulates how farmers manage soil acidity while aiming to stay profitable. The model reflects real-world decisions, such as which crops to plant, how to rotate

**Figure 1. Soil Acidity Levels Across Canada**




Note: Soil pH levels across Canada's agricultural regions, measured using calcium chloride. Large areas exhibit strongly acidic soils, with pH values below 5.5.

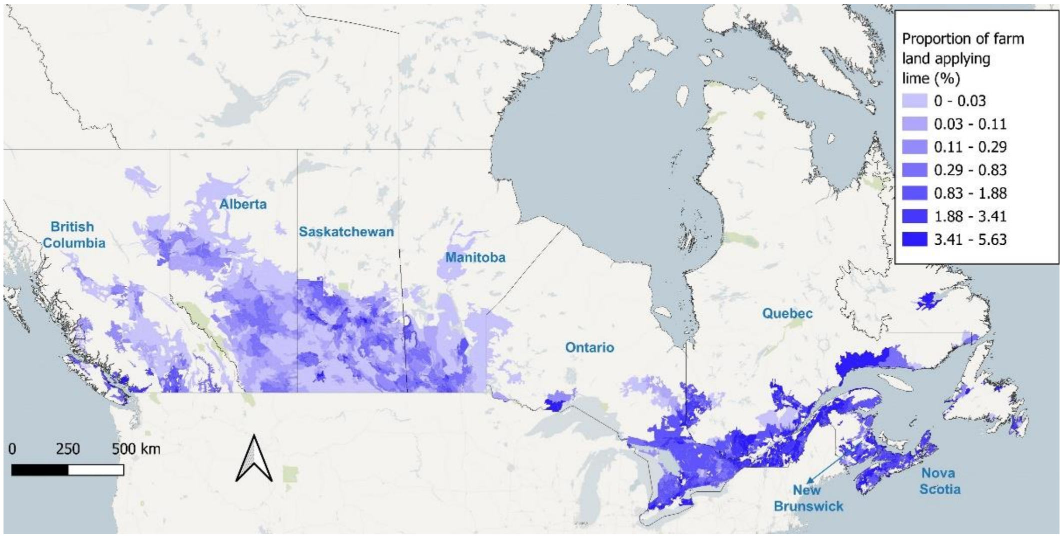
Source: Data from Soil Landscapes of Canada Version 3.2 (SLC v3.2), Agriculture and Agri-Food Canada.

them, and whether and how much lime to apply. Farmers need to make these choices over multiyear planning horizons, with a typical rotation lasting 3 years. The model simulates how these decisions play out over time, taking into account changing soil conditions, fluctuating crop yields, and volatile market prices.

A key feature of our model is that soil pH affects how well crops grow. High-value specialty crops like pulses need soil conditions to stay within a tight range. If the soil becomes too acidic, their yields drop sharply. Liming can restore pH levels—but not without cost. The practice involves capital and operating expenses, and the benefits decline over time as soil naturally re-acidifies. The model also captures the trade-off between liming and crop selection. A grower who invests in lime can expand into pH-sensitive specialty crops. A grower who does not may be forced to switch to acid-tolerant options. Realistic crop rotation constraints are also built in, such as alternating between cereals and pulses to preserve soil fertility.

To ensure the analysis reflects the realities farmers face, the study draws on real-world data to calibrate its

**Figure 2. Lime Application Rates Across Canada.**




Note: This map illustrates the share of farmland, by region, where lime is applied to manage soil acidity. Despite widespread acidification risks, most regions show lime use on fewer than 5.6% of agricultural lands.

Source: Data derived from *Census of Agriculture*: *Agri-Environmental Spatial Data 2021*, Statistics Canada.

**Table 1. Summary of Model Parameters**

| Parameter | Value | Description |
|---|---|---|
| Time horizon | 48 years | The analysis covers a 48-year period for long-term analysis |
| Inflation rate | 0.02 per year | Annual price increase (2% per period) |
| Acidification rate | 0.01 | Natural acidification of soils based on Fenn et al. (2006). Soil becomes more acidic each year, naturally and slowly reducing its fertility |
| Lime effectiveness | 0.2 | Increase in soil pH per ton of lime applied, based on Enesi et al. (2023) |
| Liming cost | 85.75 CAD/ton | Base cost of lime per ton (authors calculations*) |
| Profit uncertainty | ±30% | Yields and prices can vary randomly by up to ±30%. This captures real-world market and weather risks |
| Initial soil pH | 6.4 | Average soil pH at the beginning of the analysis (data from Soil Landscapes of Canada version 3.2) |

Notes: *Over 10 years, lime costs approximately CA$150 per ton, with 1 hectare requiring an average of 4.5 tons. Added expenses include CA$11 for application, CA$6 for transport, $0.15 for machinery upkeep, CA$1.2 for bulk storage and soil testing.

economic framework. Two tables summarize the model's assumptions: Table 1 sets the parameters for how farming decisions unfold over time, and Table 2 outlines the economics of growing different crops in Western Canada. Table 1 includes key settings like how long the analysis runs, how fast prices are expected to rise, and how quickly soils naturally acidify. It also includes the cost of applying lime and its effectiveness in improving soil health. These values are based on recent research, official estimates, and expert opinions.

Table 2 offers a snapshot of farm economics. It lists average market prices, yields, production costs, and the ideal soil pH range for crops like wheat, lentils, canola, and dry beans. These values come from provincial crop planning guides, insurance data, and historical records. Together, they help the model estimate how much profit each crop could generate under different soil conditions.

With the economic framework in place and grounded in real-world data, the next section explores what the numbers reveal. How do farmers respond when soil conditions deteriorate due to natural acidification? What happens to profitability when liming is delayed or skipped altogether? The results reveal important trade-offs, shifts in crop choices, and a clearer picture of why some growers continue to avoid liming despite its long-term benefits.

## Main Result: Acid Pushes Pulses Out

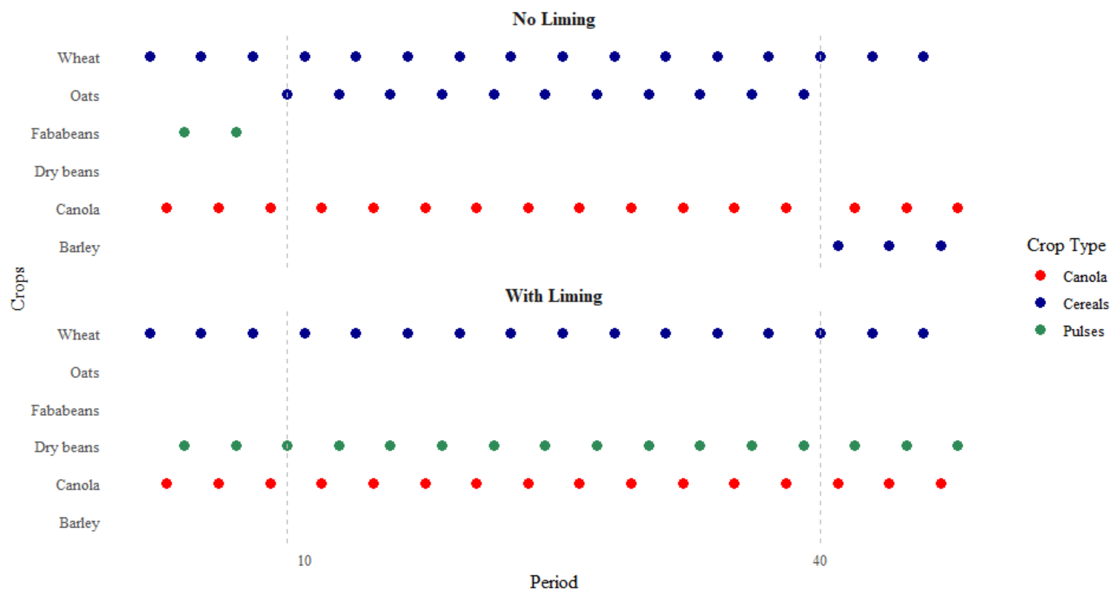
Using the economic model described earlier, we simulate cumulative profits and crop choices under two scenarios: with and without soil liming. From Figure 3, we find that there are differences in crop choice frequency. In the "no liming" scenario, we observe a clear shift away from pH-sensitive crops like pulses.

**Table 2. Crop List and Data, 2023–2024**

| Crop | Prices (CAD/tonne) | Maximum Yield (tonne/ha) | Production Cost (CAD/ha) | Optimal pH Range |
|---|---|---|---|---|
| Wheat | 378 | 4.1 | 1,415 | (6.0, 7.0) |
| Barley | 314 | 4.9 | 1,350 | (5.5, 7.0) |
| Canola | 627 | 5.9 | 1,630 | (5.5, 8.5) |
| Oats | 289 | 5.0 | 1,220 | (5.5, 7.0) |
| Dry peas | 432 | 3.5 | 1,280 | (6.0, 7.0) |
| Chickpeas | 745 | 2.7 | 1,430 | (7.0, 8.0) |
| Dry beans | 1215 | 3.3 | 1,925 | (6.0, 7.5) |
| Faba beans | 375 | 6.7 | 1,400 | (6.0, 7.2) |
| Lentils | 807 | 2.2 | 1,165 | (6.0, 8.0) |

Notes: Data comes from various sources, including the provincial crop planning guides (Government of Saskatchewan, 2023; Manitoba Agriculture, 2025), historical data from Statistics Canada, and market outlooks from Agriculture and Agri-Food Canada (2023). Specifically, farm-gate prices are based on Saskatchewan Crop Insurance 2024. Maximum yield potentials are drawn from experimental and research data (e.g., Alberta yield optimization studies, Statistics Canada reports, and irrigated crop trials). Production costs are average total costs per hectare from provincial crop budget estimates (e.g., Saskatchewan 2023 Crop Planning Guide). Optimal pH range data are extracted from existing literature and supplemented with expert opinion when empirical values are unavailable.

**Figure 3. Crop Choices over Time**




Note: The top panel represents crop choices in the no liming scenario. The y-axis lists the chosen crop in each period, and the x-axis is time (in periods). Each dot represents the crop planted in that period, color-coded by crop type (Cereals, Pulses, and Canola). The bottom panel has the same structure but shows the chosen crops when lime application is chosen by the representative farmer. Dots in a straight line mean the same crop was planted repeatedly. Dots moving between lines show changes in crop choice. In the liming panel, more green dots appear, meaning more pulse crops are grown.

Why? As soil pH gradually declines due to natural acidification, these crops become less profitable. In response, farmers are nudged toward planting more acid-tolerant cereals, which are better suited to suboptimal soil conditions. By contrast, in the liming scenario, soil pH is maintained (or adjusted) within optimal ranges. This allows farmers to include a higher proportion of profitable, pH-sensitive crops such as pulses in their rotations. The ability to sustain these crops over time contributes to greater crop diversity and potentially higher long-term returns.

In Figure 4, we depict the associated profits over time under the two scenarios. Both lines start near zero and rise as profits accumulate. Initially, the gap between the two lines is small, reflecting similar short-term decisions when pH is not yet a major limiting factor. However, as time progresses, the cumulative profit for the “with liming” scenario (blue line) clearly surpasses that of the “no liming” scenario (red line). This indicates that the long-term benefits of maintaining optimal soil pH—such as consistently higher yields and access to more profitable crops—outweigh the costs of applying lime. In contrast, the cumulative profit for the “no liming” scenario levels off or increases at a slower rate over time, which reflects the suboptimal crop choices resulting from lower pH levels in later years. By the end of the horizon, the difference in cumulative profit between the two scenarios is substantial.

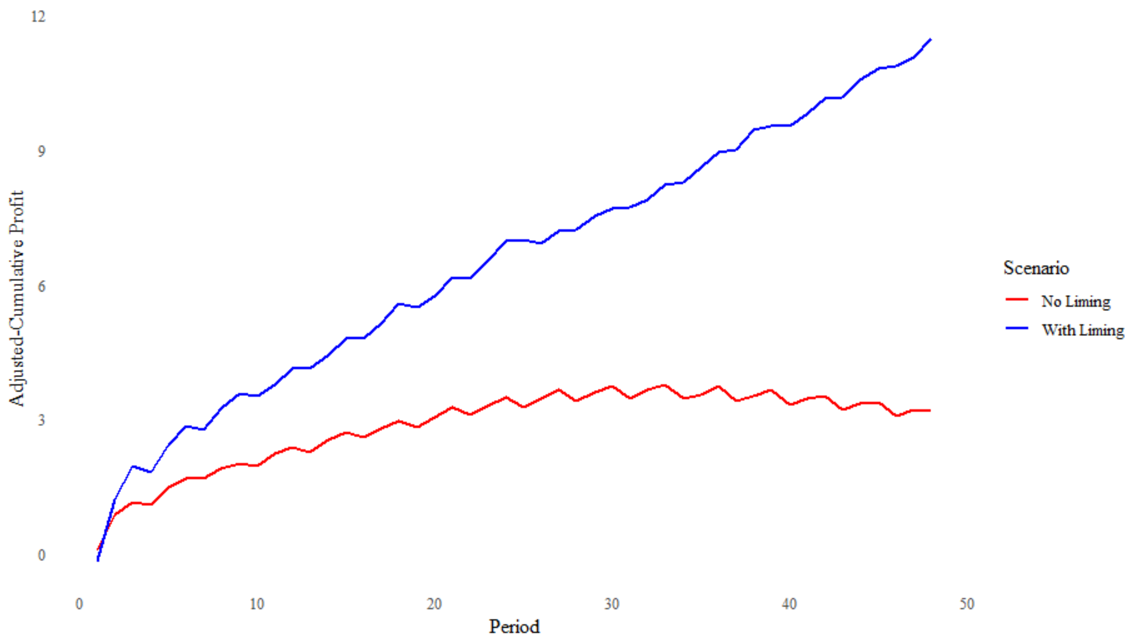
Specialty crops such as faba beans, dry beans, and lentils tend to offer higher market returns, but they also have narrower optimal pH ranges. Pulses generally require a near-neutral to slightly alkaline pH level, ideally between 6.0 and 7.5 or 8.0. Canola can also be sensitive if the pH drops too low. When lime is applied, soil pH remains closer to or within these optimal ranges, helping to preserve the yield potential of these crops. This ensures that pulses and canola remain profitable over the planning horizon. In the “no liming” scenario, as the pH continues to decline, farmers are more likely to switch to acid-tolerant crops like barley and oats.

Why is this important? Pulses are important not just for profit but also for agronomic benefits (e.g., disease break, nitrogen fixation). Keeping the soil pH in a healthier range for specialty crops can also have positive spillovers for soil health and future productivity.

## The Adoption Puzzle

If soil liming is profitable in the long run because it allows sustainable production of high-yield, pH-sensitive specialty crops, then why is its adoption rate so low? There are several possible explanations for the low adoption rate of soil liming in Western Canada. Avoiding risk, limited cash flow, or simply not knowing enough can all be factors. Here, we take a closer look at two key potential explanations: how acidic farmers believe their soil really is and whether they trust lime to solve the problem.

## Figure 4. Adjusted-Cumulative Profits over Time




Note: The x-axis is the time, and the y-axis represents the adjusted-cumulative profit, which tracks the cumulative profit across periods divided by period-specific standard deviations (measures how spread out the numbers are from the average) to adjust for risk.

First, we simulate a scenario where soil acidification is low and lime works only moderately. That is, a farmer might perceive or observe that the soil pH does not deteriorate quickly, and even if lime is applied, its impact is limited. As shown in the upper panel of Figure 5, the profit lines for "no liming" and "with liming" stay relatively close compared to the baseline scenario in the previous section. This indicates limited economic gains from soil liming under these conditions. Notably, in the short term, the red line lies above the blue line, suggesting that "no liming" can generate higher early-period profits. This outcome helps explain why some farmers might not invest in soil liming, since immediate returns appear more favorable without it. As a result, the overall incentive to adopt soil liming practices is diminished compared to the baseline scenario.

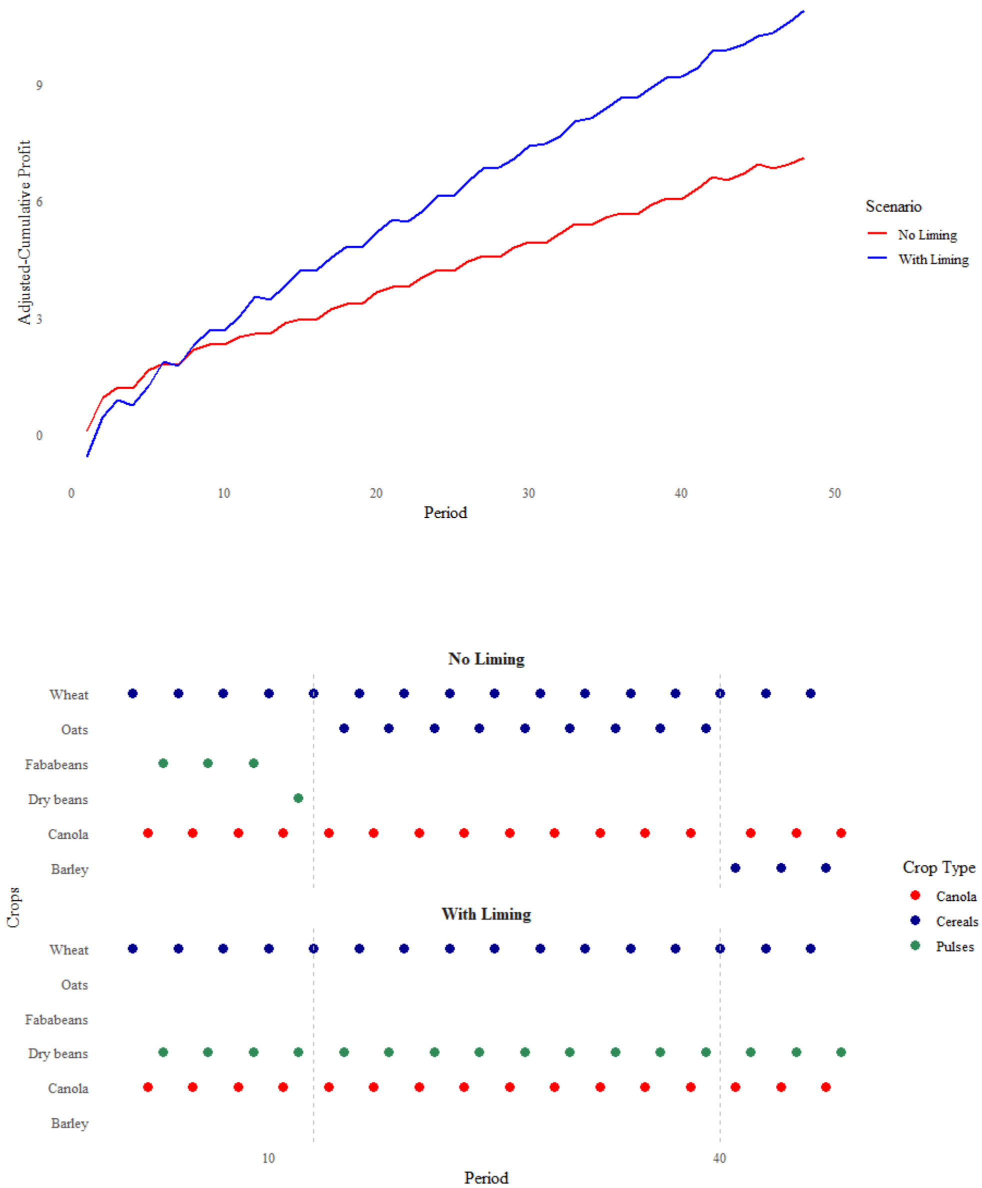
In the second scenario, we simulate a situation where the soil acidifies quickly, but lime does not significantly offset this effect (see Figure 6). Without liming, profitability sharply declines after approximately ten periods, turning negative around the twentieth period. At this stage, continuing farming becomes economically unsustainable, and farmers are likely to exit agriculture, regardless of crop rotation. Thus, even though lentils are included in the rotation, their presence has little impact since farming itself is no longer profitable. With liming, profits remain positive, but their growth is slower compared to optimal conditions. Nevertheless, liming still allows the continued production of specialty crops, such as faba beans and dry beans, though at reduced yields.

In summary, if farmers hold misbeliefs or observe that soil acidification is slow and that lime exhibits only a moderate effect, the incentive to adopt soil liming practices is weak. Conversely, in cases where site-specific acidification is very high, the adoption of soil liming becomes critically important, even though liming alone may not fully restore optimal soil conditions.

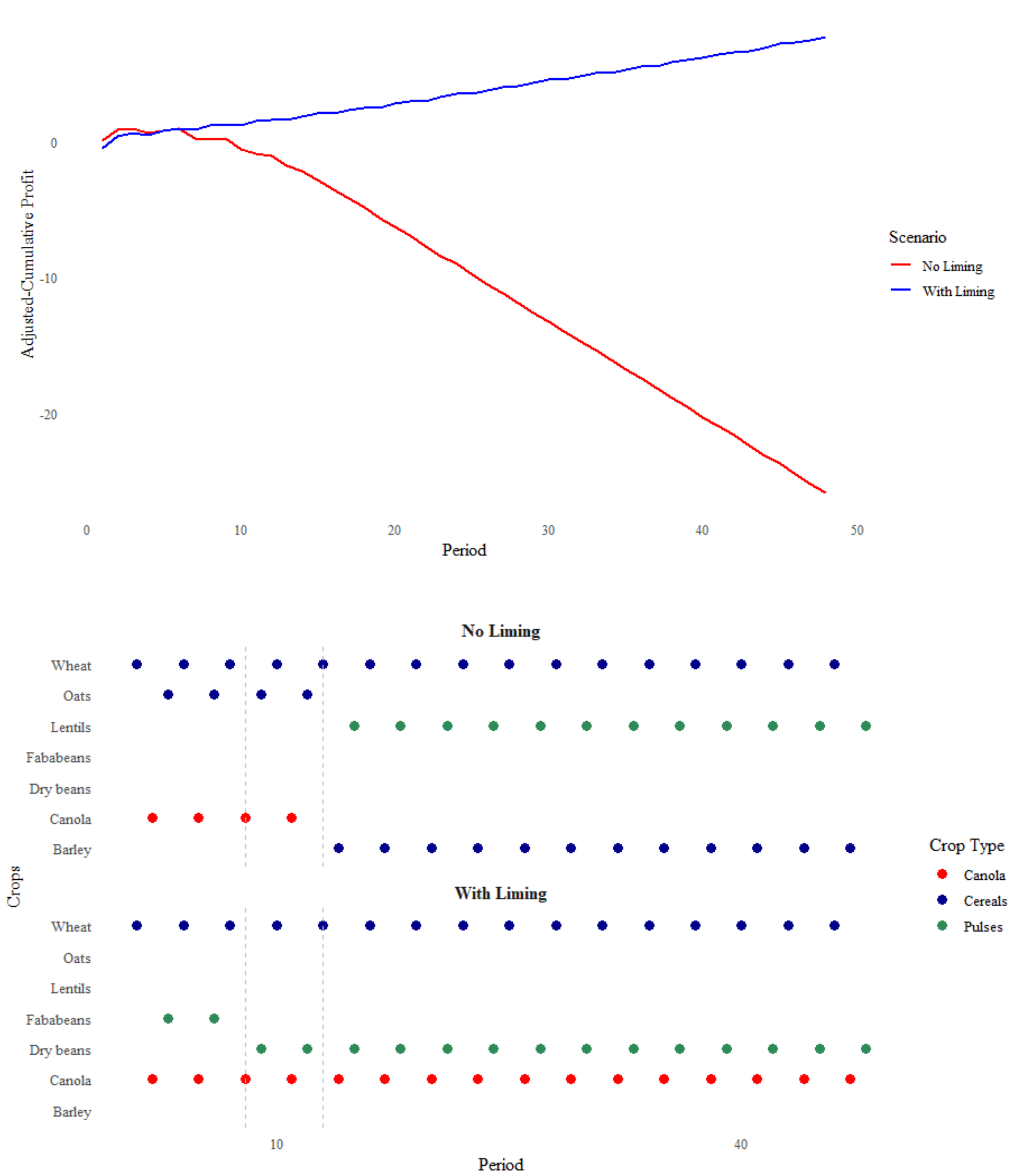
## Conclusion

Our economic analysis examined how soil liming influences long-term farm profits and crop rotations. We find that, without soil liming, natural acidification gradually pushes farmers to replace pulses with more acid-tolerant cereals. Liming maintains optimal soil pH, enabling the continued cultivation of high-value, pH-sensitive crops such as pulses and canola over the long run. However, adoption of soil liming practices depends heavily on local soil conditions and farmers' perceptions about acidification and the effectiveness of liming. The findings point to several important policy steps. First, extension services should provide clear, accurate information about soil liming and the natural risks of acidification. Second, it is important to survey farmers to find out what misunderstandings exist, especially in areas where acid soils are a big problem. Third, policies should promote site-specific soil management strategies by improving access to affordable soil testing and decision-support tools. Finally, targeted support is key. This could include subsidies for lime use, incentives for soil testing, and local guidelines for soil management. These actions would help farmers protect their soil, raise their yields, and better prepare for a changing climate.

## Figure 5. Low Acidification and Low Lime Effectiveness



## Figure 6. High Acidification and Low Lime Effectiveness



## For More Information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