DN6_25_17 "Drought Resilient Soils – optimising water capture and use in the landscape"

DROUGHT RESILIENT SOILS

CONSULTATION SUMMARY

Report developed by Felicity Turner and Dr Melissa Fraser

for the South Australian Drought Hub

Contact: Felicity felicity@turneragri.com.au
Mobile: 0400 299 087
Mel mel@soilfunction.com.au
Mobile: 0407 773 369

Australian Government
Department of Agriculture, Fisheries and Forestry
Future Drought Fund
SA DROUGHT HUB
This program received funding from the Australian Government's Future Drought Fund

Soil SUNLIGHT STRATEGISTS

Program Background

Drought Resilient Soils – Optimising Water Capture and Use in the Landscape (Project ID DN6_25_17) was commissioned by the South Australian Drought Hub to identify the knowledge, capability and investment needed to strengthen drought resilience in South Australian dryland cropping, pasture and mixed farming systems.

Project objective:

To develop a statewide, practical and adoption-focused approach that improves the capture, storage and productive use of water by combining regionally relevant evidence, skilled people, structured learning and farmer-led implementation.

Project rationale:

Statewide Drought Hub consultation and co-design in 2021 identified improved soil water management as a consistent priority. In May 2025, Felicity Turner and Dr Melissa Fraser, operating as Soil Sunlight Strategists, were engaged to build on this work and scope a future statewide investment ahead of the 2026–2032 funding period.

The project deliberately moved beyond asking what additional research is required. It examined what growers and advisers have learned from previous investments, what has changed in practice, where adoption remains constrained, and what combination of evidence, extension and capability is required to convert knowledge into sustained on-farm action.

Consultation reach and approach:

4	63	22	4
regional workshops	**workshop stakeholders**	**additional stakeholders**	**regional project concepts**

Regional workshops were held at Wudinna, Cummins, Watervale and Tailem Bend in October 2025, supplemented by smaller consultations with the Coorong Tatiara Local Action Plan reference group and MacKillop Farm Management Group. Participants included farmers, agronomists and advisers, farming systems groups, Landscape Board staff, and representatives from DEW and PIRSA.

The facilitated process explored five areas: agronomy; crop and pasture sequences; pastures; amelioration; and nutrients and fertility. Participants identified key learnings, evidence of practice change, gaps and barriers, and then co-designed regionally relevant project concepts.

Consultation findings:

The consultation found that the primary challenge is not just a lack of information; there is a larger gap in the ability to interpret evidence, understand risk and return, and apply technically sound options within variable and complex farm businesses across the themes identified in Figure 1.

From there, priority areas for investment were identified (Table 1) and the project Cultivating Capacity developed.



Figure 1. Key insights from consultation

Table 1. Priority areas for future investment

1. Soil water and plant available water (PAW) interpretation, including practical decision triggers.	2. Subsurface constraint diagnosis and cost-effective sampling and management.
3. Amelioration longevity, payback periods and economic risk across soil types.	4. Nitrogen cycling, pulses, legacy nitrogen and nutrient-water interactions.
5. Machinery–soil matching, seeding systems and soil-specific decision frameworks.	6. Stubble and groundcover strategies that balance erosion protection, establishment and economics.
7. Spatial agriculture and variable-rate technology, with stronger interpretation and ROI support.	8. Mixed farming system options, including resilient pasture, pulse and enterprise combinations.
9. Simplified evidence-based decision tools using thresholds, triggers, financial and risk metrics.	10. Human capacity and advisory support, including facilitation, financial literacy and peer learning.

These findings led directly to the development of Cultivating Capacity – Empowering People, Unlocking Soil Potential: a coordinated investment framework designed to connect capability, evidence, learning and adoption.

Proposed response: Cultivating Capacity

Cultivating Capacity is a proposed multi-year statewide learning and innovation system. Its purpose is to strengthen the three conditions repeatedly identified as necessary for successful practice change: skilled people, practical evidence and effective learning and adoption pathways.

Consisting of four interconnected components with five evidence based themes (Figure 2), Cultivating Capacity aims to create a connected statewide learning and innovation system that empowers people to translate knowledge into action, improve water capture and utilisation, and build more resilient agricultural businesses and communities.

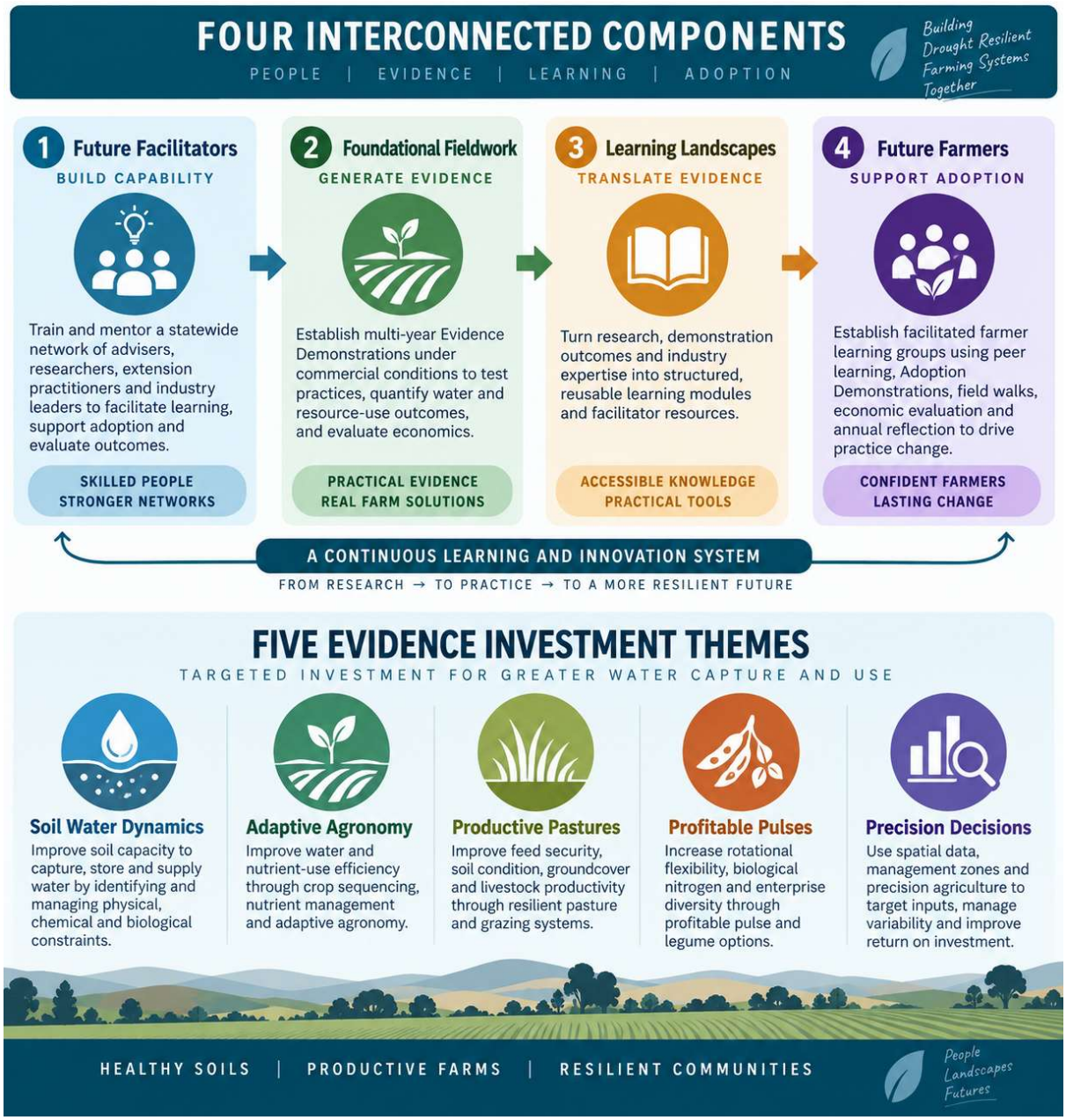


Figure 2. Outline of the Cultivating Capacity Framework

Executive overview:

The consolidated regional consultation data shows that South Australian growers face increasingly complex farming systems shaped by climate variability, soil constraints, machinery limitations, and shifting markets. While technical knowledge has improved in areas such as stubble retention, amelioration, dry sowing, disc seeding, and pulse integration, growers emphasise that the greatest barriers to adoption are economic confidence and human capacity, not lack of research.

Across all themes, growers expressed a strong need for clear return on investment (ROI) guidance, improved risk literacy, and decision-support tools that cut through complexity. Amelioration, fertiliser strategy, spatial management, machinery investment, and rotation choices all hinge on understanding financial return, longevity, and seasonal risk. Without this economic clarity, even well-proven practices struggle to be adopted at scale.

At the same time, a significant theme across the workshops was the need for greater human capacity, including access to specialised advisers, improved soil and nutrient literacy, support for early-career agronomists, and practical training to interpret soil tests, maps, variability, and multi-layered data. Growers repeatedly described themselves as time-poor and lacking "translators" who can convert complex information into actionable whole-farm decisions.

Nine major technical themes emerged—soil water, subsurface constraints, nutrient cycling, rotations, machinery, amelioration, stubble management, spatial variability, and mixed farming—but all are deeply influenced by these two cross-cutting needs: return on investment clarity and human capacity to make informed decisions.

A. Consultation Process

Hub partners were initially contacted by the SA Drought Hub around the consultation process and invited to contribute information and participate in the consultation sessions. The Drought Hub were provided with a framework to capture information of past investments and key outcomes relevant to soil water capture, storage and utilisation in dryland broadacre crop and pasture systems for review prior to the consultation so that relevant information could be drawn from if required during the consultation process. Felicity Turner and Dr Melissa Fraser from Soil Sunlight Strategists then conducted the consultation process through a series of facilitated workshop sessions.

- **Consultation period and locations**
    - Regional workshops were held in October 2025 across four key locations: Wudinna (13 October), Cummins (14 October), Watervale (15 October), and Tailem Bend (16 October).
    - Additional, smaller-scale consultations were also conducted with Coorong Tatiara Local Action Plan reference group and MacKillop Farm Management Group at their research and development planning forum.
- **Stakeholder engagement**
    - The process brought together a diverse mix of participants, including leading farmers and grower representatives, Regional agronomists and advisors, Farming systems groups, Landscape Board staff, State government

representatives from Department for Environment and Water (DEW) and Primary Industries and Regions SA (PIRSA)

- A total of **63 stakeholders** participated directly through workshops, with an additional 22 stakeholders engaged through informal discussions.

- **Methodology and facilitation**
  - Workshops employed a range of facilitation tools and participatory methods to encourage open discussion and capture insights.
  - The facilitation approach was reviewed and refined after each session to ensure effectiveness and alignment with project objectives.

  The agenda is provided in ***Appendix 1***.

- **Focus areas and data collection**

  Information was gathered around:

  - Key learnings from recent regional investments relating to the soil water cycle, exploring five key themes:
    1. Agronomy (Stubble, Seeding, Establishment and Phenology)
    2. Crop and Pasture sequences
    3. Pastures
    4. Amelioration
    5. Nutrients and Fertility
  - Levels of adoption and practice change resulting from these or other initiatives
  - Gaps in knowledge, skills, and capacity that influence farm business resilience to drought

  This is summarised in ***Appendix 2*** with the complete dataset of information presented in ***Appendix 3***.

- **Regional project concept development**

  Participants worked collaboratively to co-design regional project concepts relevant to their local conditions and priorities.

  Participants were challenged to define:

  - The purpose and intended outcomes of their proposed project
  - The key activities, timing, and responsible parties required for delivery

  The resulting regional project scopes are included in ***Appendix 4***.

- **Consultation feedback/review**
  The consultation findings were sent back to stakeholders who attended the workshops for review and feedback prior to the project development occurring.

B. Key Findings

The collated data reveals that South Australian growers operate within complex, variable farming systems shaped by soil constraints, rainfall uncertainty, rising input costs, and labour limitations. Across all workshops, several strong cross-system themes emerged.

1. Water, soil constraints, and seasonal variability underpin system performance
Understanding plant available water (PAW), soil constraints, and rainfall timing drives agronomic, nutritional, rotational, and machinery decisions.

2. ROI (return on investment) and financial literacy are fundamental drivers of practice change
Growers consistently framed barriers in terms of:

- Unclear return on investment
- High capital costs and long payback periods
- Difficulty interpreting risk vs reward
- Limited confidence in season-dependent decisions

This applied to amelioration, fertiliser strategy, disc vs tyne choice, pulse integration, rotations, soil testing, variable rate technology (VRT), and spatial mapping.
Growers are not just asking "What works?" but "What pays, and when?"

3. Human capacity building is a major system-wide gap
Growers repeatedly highlighted:

- Need for "translators" to interpret maps, soil tests, and research
- Limited specialist support (pastures, soil constraints, nutrition)
- Adviser turnover and capacity limits
- Lack of time to engage with complexity
- A need for early-career agronomist development and peer-learning

Capacity constraints limit adoption far more than lack of science.

4. Nutrient cycling, especially nitrogen (N), is poorly understood relative to system complexity
N banking, legacy N, post-amelioration nutrient management, and phosphorus and potassium dynamics remain unclear, especially under seasonal variability and diverse soil types.

5. Machinery, seeding systems, and amelioration interact strongly with soil and water
Disc vs tyne economics, seeding depth, stubble loads, and amelioration machinery access are all constrained by soil type and moisture. Growers increasingly need soil-specific, ROI-aware decision tools.

6. Rotations and mixed farming systems face agronomic and economic constraints
Pulse stubble limitations, drought risk, herbicide residues, market volatility, pasture establishment issues, and mixed-farming complexity shape rotation decisions.

7. Systems thinking is essential yet difficult to implement
Growers acknowledged that solving one problem creates another (e.g., amelioration improving water storage but exposing nutrient constraints). Integrated, whole-farm decision-making support is required.

C. Future Investment Priorities

These priorities combine technical needs with the underlying financial and human capacity drivers identified across all themes.

1. Soil Water and PAW Interpretation
Growers want practical tools to assess PAW at seeding, in rotations, and under ameliorated conditions.
→ Needs to include ROI-based triggers for sowing depth, crop choice, and dry sowing risk.

2. Subsurface Constraint Diagnosis and management
A large gap exists in detecting and managing emerging subsurface issues.
→ Requires cost-effective sampling strategies and decision thresholds.

3. Amelioration Longevity and Economics
Uncertainty around long-term ROI is a major barrier.
→ Research should quantify payback periods, longevity, and economic risks across soil types.

4. Nitrogen Cycling, Pulses and Legacy N
Clarify N-banking strategies, mineralisation, and pulse contributions in different soil types and locations.
→ Integrate financial comparisons for rotations and pulse options.

5. Machinery–Soil Matching (Disc vs Tyne; Inclusion Ripping; Mixing)
Growers want machine–soil decision frameworks that factor in performance, risk, and cost.
→ Include economic workflows to support investment decisions.

6. Stubble and Groundcover Solutions
Balance erosion protection, herbicide efficacy, and machinery performance.
→ ROI needed on stubble options (grazing, biochar, mechanical management).

7. Spatial Agriculture and VRT ROI
Spatial management adoption is stalled by interpretation challenges and lack of ROI clarity.
→ RDE must pair technical advances with economic decision tools and capacity building.

8. Mixed Farming System Options for SA
Clarify viable C3/C4 mixes, perennials, shrubs, and intercropping economics.
→ Requires enterprise mix modelling and risk/return guidance.

9. Simplified, Evidence-Based Decision Frameworks
Growers consistently asked for matrices, triggers, thresholds—not more data.
→ Decision tools must include financial and risk metrics.

10. Human Capacity and Advisory Support
This is a foundational barrier across all themes.
Includes:

- Financial literacy and risk literacy

- Interpreting soil tests, maps and variability
- Increased advisory capacity
- Support for early-career agronomists
- Peer-based learning models

→ Capacity-building is a core RDE priority that influences all others.

Addressing these systemic barriers will be critical to enabling growers to adopt new practices, manage risk, and improve resilience in low and medium rainfall environments.

D. Recommended Future Investment Strategy

"Cultivating Capacity – Empowering People, Unlocking Soil Potential" a multiyear investment strategy has been developed in response to this consultation. It is a strategic investment that ais to create a connected statewide learning and innovation system that empowers people to translate knowledge into action, improve water capture and utilisation, and build more resilient agricultural businesses and communities by providing;

1. **Skilled people** capable of facilitating learning, supporting adoption and connecting growers with trusted information.
2. **Practical evidence** generated under commercial farming conditions that demonstrates what works, where and why.
3. **Effective pathways for learning and adoption** that enable growers to confidently evaluate, implement and adapt new practices.

The full investment proposal is outlined in the document ***3. Cultivating Capacity Investment Proposal*.**

Appendix 1.

AGENDA (Varied slightly for each location depending on time of session)

9.00am	Welcome from the Drought Hub (Lucy Porter, SADH)
9.10am	Welcome from facilitators and outline of the programme for the day
	Participant introductions
9.30am	Setting the scene – Context for the day
	Facilitated activity – "The water cycle"
9.50am	Table activity – Key learnings and gaps in knowledge and skills across themes (Bus Stop process with all participants contributing to all themes)
10.45am	BREAK
11.05am	Acknowledge gaps in the themes.
11.20am	Identify 3-4 activities to scope up
11.30am	Table activity – Project development (Bus stop activity with all participants contributing to all projects)
12.30pm	Summarise each theme and seek any clarity required
	Outline next steps
	Feedback around the process and closing comments
1.00pm	LUNCH

Appendix 2.

SUMMARY THEMES IDENTIFIED THROUGH CONSULTATION
(Complete data set attached in Appendix 3)

1. AGRONOMY (Stubble, Seeding, Establishment, Phenology)
Key Learnings

- Stubble retention improves water storage, soil health, and erosion control.
- Pulse crops provide nitrogen and rotational benefits but often leave low cover.
- Disc vs tyne performance is highly soil- and moisture-specific.
- Establishment success depends on soil moisture location, seeding depth, and row placement.
- Phenology, variety selection, and root depth strongly influence water use and resilience.
- Herbicide resistance is increasing; harvest weed seed capture (HWSC) is effective but slows harvest.
- Soil constraints often dictate seeding outcomes more than machinery choice.

Gaps / Barriers

- Stubble management solutions (grazing, biochar, carbon value, residue thresholds).
- Confidence in dry sowing under low moisture.
- Lack of simple tools to interpret PAW at seeding.
- Limited guidance on on-row vs inter-row value and ideal row spacing/density.
- Discs on non-wetting sands / hairpinning on slopes.
- Few low-rainfall variety options (pulses, canola, cereals).
- Herbicide residue uncertainty in tight rotations.
- Complex seeding systems; limited tech support.

2. PASTURES
Key Learnings

- Multi-species, C3/C4 mixes and perennial pastures offer soil and system resilience.
- Pastures support groundcover, nitrogen cycling, and flexible grazing/hay options.
- Containment feeding and grazing management are improving practice.

Gaps / Barriers

- Lack of pasture specialists and regional capacity.
- Limited herbicide-safe pasture species.
- Establishment difficulty in low rainfall and ameliorated soils.
- Economics of hay vs grain vs grain-and-graze poorly understood.
- Limited knowledge about native grasses and shrubs.
- Pasture–crop integration restricted by rotations and herbicide residues.

3. CROP and PASTURE SEQUENCES
Key Learnings

- Pulses are essential for N, system productivity, and risk diversification.
- Rotations materially influence PAW, cover, nutrient supply, and disease cycles.
- Break crops stabilise yield and reduce input dependency.
- Market signals and risk appetite shape rotation choices.

Gaps / Barriers

- Unclear N legacy and mineralisation dynamics.

- Poor understanding of moisture legacies and evaporation losses.
- Pulse reliability under drought + low stubble cover erosion risks.
- Herbicide residues constrain rotation flexibility.
- Need updated crop lower limit (CLL), transpiration efficiency (TE) and evaporation losses for modern varieties.
- Limited pasture integration due to economics and herbicide compatibility.

4. AMELIORATION

Key Learnings

- Growers understand methods (liming, gypsum, ripping, clay mixing).
- Amelioration improves water holding, root exploration, and yield potential.
- Soil testing pre-amelioration is essential.
- Amelioration requires long-term, whole-farm planning.

Gaps / Barriers

- Emerging subsurface acidity and sodicity poorly understood.
- Confusion around sampling depth/method; soil tests seen as expensive or unclear.
- Clay quality, access, mixing effectiveness — high variability → risk.
- Longevity of amelioration and ROI unclear across soil types.
- Machinery access, cost, and regional availability limited.
- Limited extension for post-amelioration nutrition and rotations.
- Confusion between treating symptoms vs root causes.

5. NUTRITION and FERTILITY

Key Learnings

- Fertiliser efficiency is critical as costs rise.
- N cycling is complex; legacy N and mineralisation more important than expected.
- Phosphorus (P) availability strongly influenced by soil pH and PBI.
- Amelioration alters nutrient demand, access, and behaviour.
- Spatial agriculture (VRT) improves targeting when interpreted correctly.

Gaps / Barriers

- Economic clarity on fertiliser ROI.
- Poor understanding of biological inputs and foliar products.
- P needs unclear in high pH, high PBI soils; K needs unclear in all soils.
- Micronutrient thresholds missing for lentils and canola.
- Soil test interpretation gaps; sampling depth confusion.
- Limited advice on post-amelioration nutrition.
- VRT and spatial data too complex → growers need interpreters, not more layers.

Appendix 3. Key Learnings, Practice change and Gaps in Knowledge and Skills.

AGRONOMY (Stubble, Seeding, Establishment and Agronomic Practices)

Category	Key Learnings	Gaps / Barriers to Adoption
KNOWLEDGE AND SKILLS	**Stubble Management** • Pulses increase wind erosion • Stubble management and utilization • Importance of retaining groundcover in cropping systems • Stubble relationship with frost intensity • Summer weed control for moisture conservation • Soil constraints (as they influence residue management and erosion) • Stubble height improves water storage but makes herbicide management the following season difficult • Harvest weed seed capture systems can be effective but slows down harvest	**Stubble Management** • Skills to measure and manage groundcover • High stubble load risks • Low Pulse stubbles • Stubble management opportunities; biochar, long-term carbon source • Stubble to biochar • Herbivore grazing • Uneven grazing • Farmers ground-truthing (as it relates to stubble cover) • Farmer ability to ground truth paddocks (expanded to include soil and stubble context) • *Relationship between good soil health and water access (R)*
	Seeding Strategies • Deep vs shallow seeding • Tyne vs disc/stripper economics • Right machine per soil type • Discs vs tynes in non-wetting sands when dry sowing • Increased use of disc seeders • Fertiliser use and efficiency • Fertiliser/seed separation • Acidity (pH) mapping	**Seeding Strategies** • Matching species to land, soil type, and end use (mechanical/software issues, lack of tech support) • Soil moisture needs differ • Ideal seeding depth; decision matrix (soil type, moisture location, residual herbicide, etc.) • *Chemical residues (R)* • Dry sowing confidence low • Disc seeders and herbicide efficacy • Disc seeders on sandy soils and hairpinning on hilly soils

	• On-row vs inter-row potential benefits (needs more work) • Role of long coleoptile varieties and their benefits • Soil constraints (placement and machinery considerations) • Herbicide residues • Herbicide resistance is increasing	• Improved establishment with tyned seeders; inter-row sowing, cross-sowing (15°) • Furrow finish issues • Seeding complexity • Seed coatings • Seeder flexibility • Pre-sowing germination herbicide • Low rainfall variety gaps • Virtual fencing (grazing management to protect crops) • Soil/site variability (site-specific management) • Machine-soil matching • Disc maintenance • Soil variability • Weed/herbicide resistance • Soil moisture gaps • On-row vs inter-row – investment worth it? (water retention, harvesting, nutrient management, salt, sodicity, cost vs machinery) • Optimal row spacing and seeding rate/density for soil types • Soil probe interpretation • PAW gaps and soil characterization • PAW at seeding to make a more informed decision • Understanding extent of soil moisture balances • Barrel effect – as we fix one limitation another may emerge (integrated systems thinking)
	Plant Phenology • Lentils shallow rooting • Canola root depth • Canola density (interaction with sowing date) • Varietal selection	**Plant Phenology** • *Low rainfall variety gaps (timing and stress tolerance) (R)* • Soil moisture needs differ (affects growth stages) • Seed coatings (impact on germination timing)

		Economics / Decision Making • Dry sowing confidence and risk management • On-row vs inter-row – cost vs benefit • Matching species to land and end use (economic value of crop choice) • Seeder flexibility and machinery selection (cost-effectiveness) • Soil/site variability (site-specific investment decisions) • Stubble management opportunities as a long-term carbon/soil investment • Furrow finish issues (impact on establishment success and yield potential) • Improved establishment with different seeding machinery (tynes vs discs)
		PASTURES **Foundational Knowledge and Capacity** • Basic understanding of plant physiology and grazing management • Pasture experts lacking
		Genetic and Species Opportunities • *Plant breeding investment (R)* • *Mixed pasture species (C3/C4) opportunities (R)* • Multi-species opportunities for SA • Limited viable pasture mixes and suitable herbicide packages • Perennial pasture systems and establishment to capitalise out of season rainfall • Native grasses and shrubs in grazing systems

		System Design and Function • Out of season green cover needed • Opportunities: mixed/inter-cropping economics • Pest management (goats) in eating established pastures **Application and Decision Support** • Grain and Graze (low rainfall environments) • Decision support hay vs grain vs standing
Practice Change	• Increase in disc seeders (number are rising but still limited) • Reduced burning • Dry sowing adopted widely • Disc systems rising but limited • Containment feeding effective • Utilising machinery to full potential (VR Tailem Bend) • Increased use of splitter boots and hybrid disc systems • Fertiliser placement important • Increased harvest weed seed capture	
Additional comments		

CROP AND PASTURE SEQUENCES

Category	Key Learnings	Gaps / Barriers to Adoption
Knowledge and Skills	**Nitrogen** • Pulse economics including legacy N • Hyper-yield cereals need pulses • Legumes in pastures • Lentils + beans • Importance of break crops (for N replenishment) • Best crop sequence importance (impact on N cycling) • Lentil decision tree (nitrogen focus in rotations)	**Nitrogen** • N-banking knowledge; won't grow hyper-yielding crops with bagged N • Nitrogen legacy • Understanding the nitrogen benefits of different pulses • Spatial variability of fixation in pulse systems • *Mineralisation study (R)* • Validating and demonstrating Rohan Brill's work (legacy N focus)
	Soil Water • Soil limitations knowledge • Different impacts of crop sequences and rotations on soil water and nutrient holding capacity • Canola/lucerne water impacts • Lentils/canola/peas/chickpeas cover risk • Intercropping lucerne • Break crop project: rainfall/soil interactions • Breeding for tolerance (salt/sodicity)	**Soil Water** • Moisture legacies • Soil health + water access • Crops to use evaporation-prone soil water • Lentils drought unreliable • Soil type gaps – do we sow cereals on sandhills • Pre-sowing germination • Out-of-season green cover needed • Perennial pasture systems and establishment to capitalize on out-of-season rainfall
	Markets / Economics • Pulse economics including legacy N (financial return and rotational benefit) • Need 2 cereals/4-year rotation (market planning, risk management) • Mix shifting (crop choice to optimize returns) • Sustainable rotations (economic resilience)	**Markets / Economics** • Validating and demonstrating Rohan Brill's work; economics of pulses based on yield and legacy N-value • Profitability • Pulse alternative end uses

	• Best crop sequence importance (economic and agronomic balance) • Lentil decision tree (profit vs risk) • Importance of break crops (yield stability, marketable outcomes) • Herbicide residues (costs and rotational implications)	• Lack of stubble cover from pulses on vulnerable soils (economic risk management) • Chemical use vs profit • Lentils – economic analysis of forgoing sub-optimal yields in poor years to bank moisture • Funding gaps • Carbon neutral alternative uses • Carbon messaging inconsistent • Multi-species opportunities for SA • Opportunities: mixed/inter-cropping economics • Sowing fodder crops instead of historic pasture phase due to herbicide impacts • *Plant breeding investment (R)*
		Decision Making / Matrices • Risk appetite change • *WUE data outdated (pulse and canola CLLs and TE's) (R)* • Crop sequence triggers • Understanding changes in inputs required with a changing system • Re-visit Grain and Graze program (integrate mixed farming systems) • Terminating crops (mixed cropping/intercropping and termination) • Exploratory matrix of legumes/crops for biomass • Break crop thresholds • Decision support: hay vs grain vs grain and graze • Grain and Graze (low rainfall environments) • Mixed pasture species (C3/C4) opportunities • Pasture experts lacking • *Limited viable pasture mixes and suitable herbicide packages (R)*

		• Basic understanding of plant physiology and grazing management • Pest management (goats) in established pastures
PRACTICE CHANGE	• Increased lentil area (particularly with amelioration) • Tighter rotations • Increased adoption of herbicide tolerant varieties • Earlier sowing • Varietal season match • Amelioration to match crop rotation (e.g. Lime before lentils) • Grazing barley success • Containment feeding • Break crop uptake • Grazing management improvements; managing pastures for rest • Species adaptability and varietal selection for season length	
Additional comments	LPF decision tree for lentil production currently underway (MRLB)	

AMELIORATION

Category	Key Learnings	Gaps / Barriers to Adoption
KNOWLEDGE AND SKILLS	**Knowledge and Understanding** • Sandy soils knowledge has improved • Mallee seeps knowledge improved • Subsoil project (deep placement gypsum etc) • Grower interest in nutrient methods • Near-surface constraints more common than people realise – assumption that problems are too deep and too expensive to treat • Soil type variability – not all soils respond the same way • Know bucket size, texture, chemical and physical constraints • Know it all. Info is available. • Info overload? (yield maps, soil maps, precision)	**Knowledge and Understanding** • Weak understanding • Constraint ID – may be some gaps • Near-surface vs subsoil constraints – subsurface sodicity and acidity developing below 10 cm, difficult to address • Subsurface acidity emerging on sandhills – different soil sampling strategy needed • Salinity and sodicity confusion • *Boron/aluminium interactions with other constraints (R)* • Building organic carbon in ferrosols and other soils where OM breaks down rapidly • Longevity of responses uncertain (both productivity and economic) and ROI for addressing constraints, particularly when combined with gypsum/lime • Holistic "farm" view needed – fixing one thing can affect another; small, single-topic learnings hard to integrate at farm level • *Drying potential of soil at sowing time – not well understood (R)* • *Dry sowing is a different experience for plants than sowing with moisture – need to understand this (R)* • Subsoil water understanding – when establishment will occur (soil conditions, rainfall) • Weather forecasting limits decision making • Limited tech uptake to understand differences in soil water 'bucket'

		• Data analysis gaps – multivariate approaches needed to integrate agronomic and environmental data (e.g. PCA for WUE, phenology, timing)
	Diagnosis and Testing • Soil testing before is very important; ID constraints • Soil tests lacking • Soil/plant interactions unclear • Sub-surface sodicity/acidity effects uncertain	**Diagnosis and Testing** • Need more soil characterisation – PAW • Soil test costs can be high • Testing costs can be prohibitive and difficult to interpret; most agronomists not soil specialists and vice versa • Tailored info lacking • Sometimes treating symptoms and not root cause • Right tool for right constraint, on your farm and soil type – linked to bucket size • Reliming intervals unknown (economics) • Gypsum addition to saline soils – confusion among ameliorants (products, rates, timings) • Wrong amelioration rates • Gravel soils – WUE, root growth, nutrition, potassium (poor benchmarks for SA soils), phosphorus requirements • Heavy clay soils – structural issues, high PBI, low P, poor WUE • Rocks + Ironstone + Lime + Mn • Saline soil management – subsoil water use where high water table; how to increase water use?
	Amelioration Options and Processes • Addressing non-wetting/compaction • Clay spreading + mixing fixes water repellence, increases water holding capacity and nutrition • Liming addresses acidity • Gypsum addresses sodicity	**Amelioration Options and Processes** • Where/when to apply ameliorants – manures etc.; right clay, right rate, other organic amendments • Clay access issues (Upper EP, Mallee, Coomandook) – economic mitigation strategies? • Disc vs tyne issues – related to soil type

	• Profile mixing effects – sometimes brings toxicities to the surface • Best practice sequences • Ideally a one-pass operation is best • Not all clay is equal • No silver bullets to the machine used; regional and within-region differences • It's a lot bigger than just ripping/delving	• Clay mixing not always effective • District machinery gaps • Costs of and access to machinery • Labour/contractor costs • Labour force limitations • Changes in agtech and spatial application tech can make it difficult to implement • Economics unclear for some machine types (inclusion ripping) and limited availability • Artificial drainage – types (tile, mole etc.), where, cost effectiveness? • *Nano gypsum/lime (R)* • *Fodder beet/feed radish as a tool to break hardpans (R)* • *Need to explore opportunities for treating other parts of the paddock (heavy soils) (R)* • Alt. stabilisation methods – need for a "quick reference guide" (cover establishment, machine options, unintended consequences) • 'Single pass' amelioration (rip, spade, sow) – opportunity to demonstrate
	Implementation and Management • Follow-up advice needed after amelioration • Nutrition management in years after amelioration very important • Getting cover back on is crucial • Rotational choices before and after are important • Use opportunistic rainfall for salinity amelioration – seeding window • You can't do it all the day before sowing – do a bit every year, justified financially and logistically	**Implementation and Management** • Extension packages needed for amelioration – how to tailor to your own farm (what, where, when, how); timing and risk management need work • Nutrition strategies post-amelioration • Crop selection and nutrition needs post-amelioration, including capital applications • Opportunity for soil-type-specific extension, utilising existing research • Farmer–agronomist relationships need rebuilding; shared knowledge and 'woolshed workshops'

		• More education required for consultants/professionals – lack of capacity in regions • TopCrop-style groups for young growers and early-career agronomists/advisors – more flexible model needed • Staff changeover issues make group/informed decisions difficult • Risk management in grazing systems – when to graze vs protect soil, soil- and season-dependent • Sand risk management very high (erosion) • VR not common for nutrients; more so for lime • Uptake measures needed
	Outcomes and Reflections • Can increase productivity, but is a long-term investment	**Outcomes and Reflections** • Low rainfall economics overlooked • *Amelioration impacts on carbon sequestration – methodology lacking for SA (R)* • Opportunity to demonstrate productivity/economic outcomes • Longevity and ROI uncertainties for combined treatments (lime + gypsum + others) reiterated
PRACTICE CHANGE	• Heavily adopted • Reduced disturbance and stubble retention • Dry sowing success variable • Early sowing • Risk management/timing • Manage non-wetting soils • Addressing seeps • pH mapping • Liming VRT	

	• Liming ROI? • Amelioration (ripping/spading/clay/liming) • Ripping/claying sand • Deep ripping • Clay spreading/delving/spading • Top-dress apps • Rotations incl. legumes = better structure, infiltration, more leftover for mineralization • Decarbonisation links
Additional comments	

NUTRITION and SOIL FERTILITY

Category	Key Learnings	Gaps / Barriers to Adoption
KNOWLEDGE AND SKILLS	**Nutrient Efficiency and Management** • Increased fert efficiency importance and ROI • Fert applications must match new yield potential in ameliorated soils • Soil/plant testing for improving fertiliser recommendations • Better N applications (spreading) • Yield/protein data capture • Know where we need to apply different rates • Spatial management • VRT adoption • Limit loss and maximise gain • Nutrient balance • Better understanding of nutrient balance	**Nutrient Efficiency and Management** • Fert ROI calculation gaps • Fert economics/ROI • Fert decision challenges • Poor fertiliser use efficiency • High input costs / Fertiliser costs • Limited budget for fertiliser • N + P in late start – know we need more, but not well adopted • Variable rate – where is the best ROI in the system (N + P, Lime) • VRT under-used – support and extension needed for growers at different stages • VRT complexity / VRT investment incomplete • Profitability of PA unmeasured • Tools such as yield mapping, technology – need to get maps into spreader; NDVI helps fill gaps • Remote sensing – need cheaper ways to map soils and variability (NDVI + pH) • Pinpoint spatial management for complex soil types (beyond dune/swale) • Spatial management – levels of accuracy and effort required • “The right map at the right time” • Need a translator to interpret maps and results • Ground-truthing precision maps with soil and tissue tests to know what to put where and why • $ labour to collect soil samples + analysis costs → need to understand ROI

		• $60 K protein monitors • N partitioning across seasons • Feed the system, not just the crop • Can't afford to miss a good season, but can't afford to oversupply in a bad one • Decision-making with information that keeps changing • BOM and rainfall forecast limitations • Fertiliser ROI – economics and decision-making support needed
	Nitrogen Cycling and Biological Inputs • N banking (Cummins) • Crop N requirements – N banking / N efficiency • N losses less than thought • N cycling across seasons is more than we realised • Natural N mineralisation in cereals • Need root access to N early • Can't grow hyper-yielding crops from a bag – need legumes and to build nutrition • Stubble retention = N tie-up • Leaching not as big an issue as we thought	**Nitrogen Cycling and Biological Inputs** • N banking gaps / N banking (Upper EP) • Cost of nitrogen – biggest barrier to closing the yield gap • How regularly to grow pulses, and their "bagged N" equivalent • What are the other benefits of legumes – microbiology, carbon forms, water, soil structure • Benefits of legumes beyond N • Foliar/biological input uncertainty • Liquid urea + fulvic acid – not understood • Gap in foliar sprays – biostimulants and hormones • OM integration poor • Manures/organic amendments – need to understand nutrient supply, growth impact, weed/contamination risks, PFAS issues • Biology destruction from amelioration • Biological fertility – broader than soil tests • Understanding microbiology and its role in mineralisation and plant health • Impacts of herbicides/fungicides on biology • VAM levels

		• Impact of plant species diversity on biology and nutrient cycling • *Regenerative farming – more data needed to increase scale/intensity and adoption (R)* • Lack of carbon methodologies for SA farming systems
	Phosphorus, Potassium and Trace Elements • Extra N and P (++) needed in a late start • A long history of P application in dry starts doesn't mean you have enough P available • Soil type complicates P management • K is an issue (can be) and impacts on WUE • Trace elements – important to have access early	**Phosphorus, Potassium and Trace Elements** • *Unsure P rates on high pH / PBI soils (R)* • Inconsistent K responses / K responses unclear • Soil type, pH, PBI – considerations for P management • Expensive P/K mapping • P guidelines need updating • Soil critical thresholds • Lentil macro and trace element requirements • *Trace element guidance / critical values lacking for pulses and oilseeds – particularly lentils (R)* • *Are we seeing calcium deficiency (sap vs tissue testing) (R)* • Fertiliser toxicity factsheets outdated • N + P in late start – known need but poor adoption
	Soil Condition, Amelioration and Nutrient Access • Fixing acidity improves nutrition in non-cereals • Acidic soils – liming VRT + biochar • Soil carbon/health • Building soil carbon: chicken manure, biochar, biosolids • Soil type/nutrient limits • Amelioration ROI • On-row infiltration	**Soil Condition, Amelioration and Nutrient Access** • Amelioration vs fertiliser applications • Longevity of soil amelioration – nutrition "kick" early on, not sustained • Amelioration longevity • More work on other soil types needed • Rainfall implications for amelioration response • Soil testing limitations – only testing top 10 cm • Soil test variation

		• Aggregated vs incremental vs horizontal sampling – what's appropriate? • Knowledge gap – why sample 0–10 cm and when to shift to horizontal • Soil test interpretation lacking • How often to test? • *Sap testing (R) / Lack of calibration data* • Lack of tech support / Lack of support • Adviser knowledge lacking • Considerations for soil type, pH, PBI • Expensive P/K mapping • OM integration poor (also biological) • Amelioration ROI link to nutrient efficiency • *Dry seeding in grey calcareous soils with phosphoric acid (R) – test with early adopters*
	Water Use Efficiency and System Setup • Plant available water – Water use efficiency • Soil bucket (water) can be modelled against decile and soil type (Yield Prophet link) • Marginal farming systems need soil setup to provide plants best opportunity to produce • Dry seeding risk • Rotations	**Water Use Efficiency and System Setup** • Rainfall implications (linked to amelioration and nutrient uptake) • Impact on WUE from biology and calcium/nutrient interactions • Residual chemicals – persistence in low rainfall systems • Farm size + biosecurity → enterprise mix limitations (continuous cropping) • Dry seeding risk / very important as dry sowing increases • N and P management under late start conditions • 3D soil modelling to link soil variability and yield potential
	System Thinking and Attitudes	**System Thinking and Attitudes**

	• Intensive farming is not sustainable (pushing the boundaries) • Differences in managing nutrition between annual crops and perennial pastures • Attitude shift: livestock low input and low risk → higher costs (e.g. P for pastures) changed view	• Fert ROI and economics – knowledge packaging needed • Having the research available to access • Packaging the information in an easily accessible manner • Making use of existing/older generational knowledge • Literacy and knowledge gaps • Need a "translator" – turn maps and results into practical decisions • Understanding the most limiting factor and addressing that first • Lack of support and extension capacity • Adviser knowledge and tech support gaps • Time-poor for adoption • High complexity of precision tools reduces uptake • "Feed the system, not the crop" – systems-thinking mindset shift
Practice Change	• Increase in continuous cropping (livestock reduction) • Price driven, workload due to labour availability and cost; competing more for time • Soil amelioration – better understanding of costs versus return • Rotations – good example of competing priorities – 1 versus 5 yr return • Understanding that different paddocks need treating differently • Soil testing improvements • P+ high PBI in heavy soils • More nutrition applied • More consistent N applications • Timing of nutrient applications is critical • Spatial layers for N • VRT adoption • VRT Liming – more potential than adoption	

	• Organic amendment use increasing • Dry seeding – understanding where moisture is and potential issues • Including tech – soil moisture probes • On row sowing – influences water infiltration, nutrient access, OM accumulation	
Additional comments		

Appendix 5. Research Gaps

1. Soil Constraints and Soil Health
    - Relationship between soil health and water access
    - Boron/aluminium interactions with other constraints
    - Drying potential of soil at sowing time — not well understood (R)
    - Nano-gypsum and nano-lime as potential soil treatments (R)
    - Opportunities to treat other under-managed paddock zones (e.g., heavy soils) (R)
    - Amelioration impacts on carbon sequestration — methodology lacking for SA (R)
    - Fodder beet/feed radish as tools to break hardpans (R)

2. Crop Nutrition and Soil Chemistry
    - Chemical residues
    - Soil nitrogen mineralisation study
    - Uncertainty around P rates on high pH / high PBI soils (R)
    - Trace element guidance and critical values lacking for pulses and oilseeds, especially lentils (R)
    - Potential calcium deficiency — sap vs tissue test discrepancies (R)
    - Sap testing — lack of calibration data (R)
    - Dry seeding on grey calcareous soils with phosphoric acid — testing with early adopters (R)

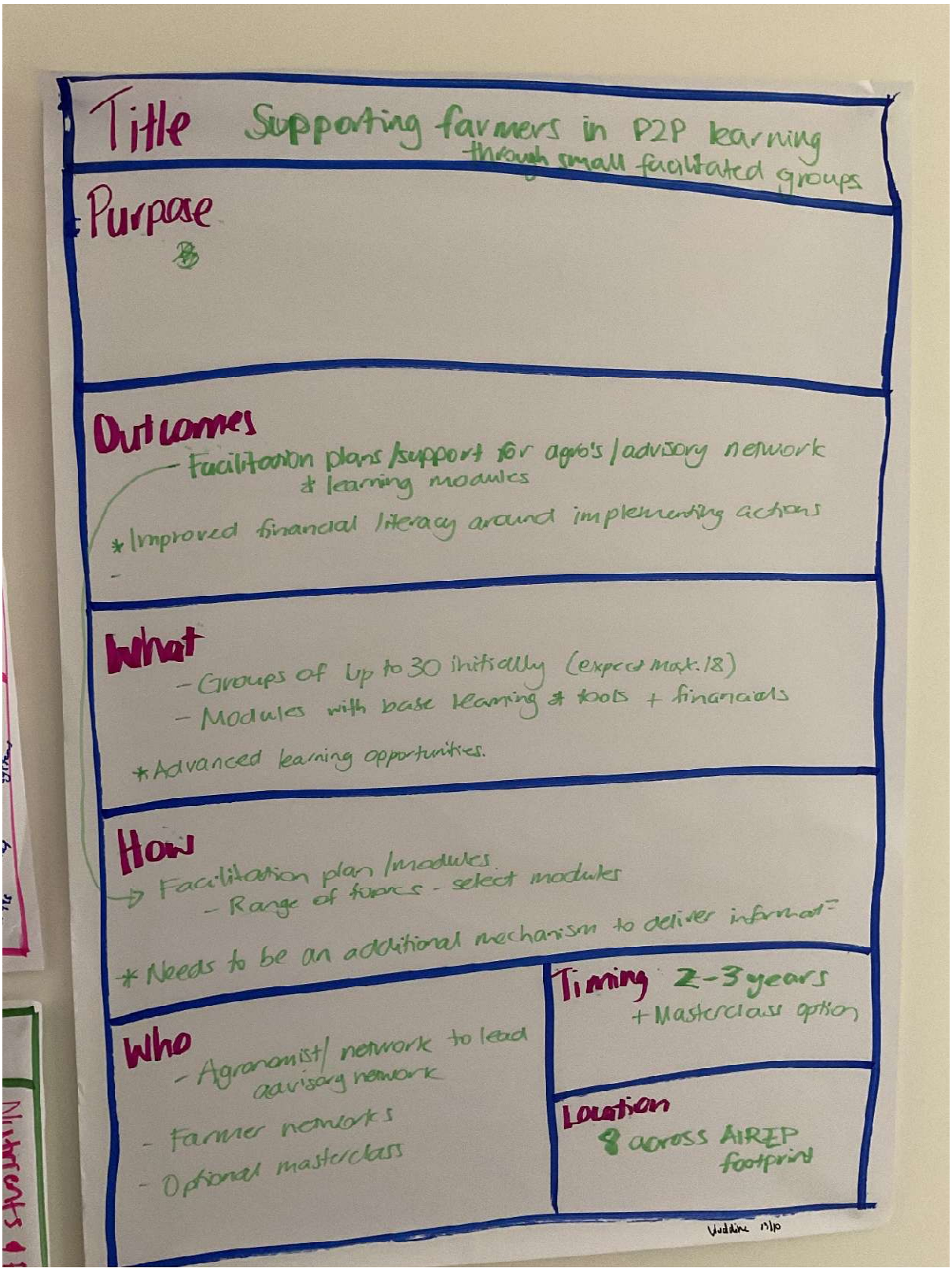
3. Crop Genetics and Plant Physiology
    - Low rainfall variety gaps (timing, stress tolerance)
    - Investment needs in plant breeding
    - Root system behaviour across crop species, systems, and climates
    - Cultivar capacity to cope with different soil characteristics
    - Dry sowing vs sowing into moisture — how plant responses differ (R)

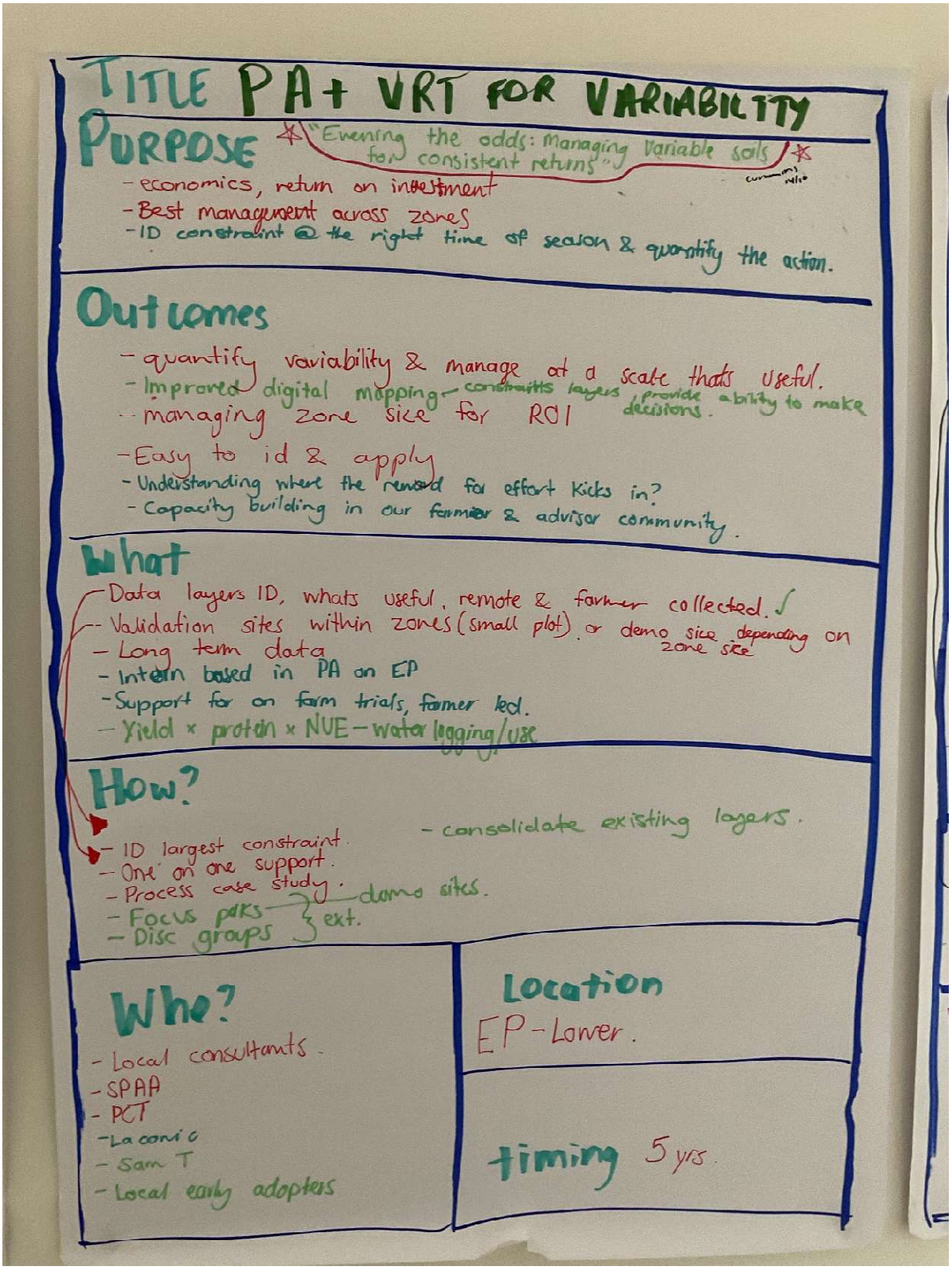
4. Pastures, Mixed Systems and Forages
    - Opportunities for mixed C3/C4 pasture species
    - Limited viable pasture mixes and suitable herbicide packages
    - Fodder beet/feed radish as system tools (also relevant under soil constraints)

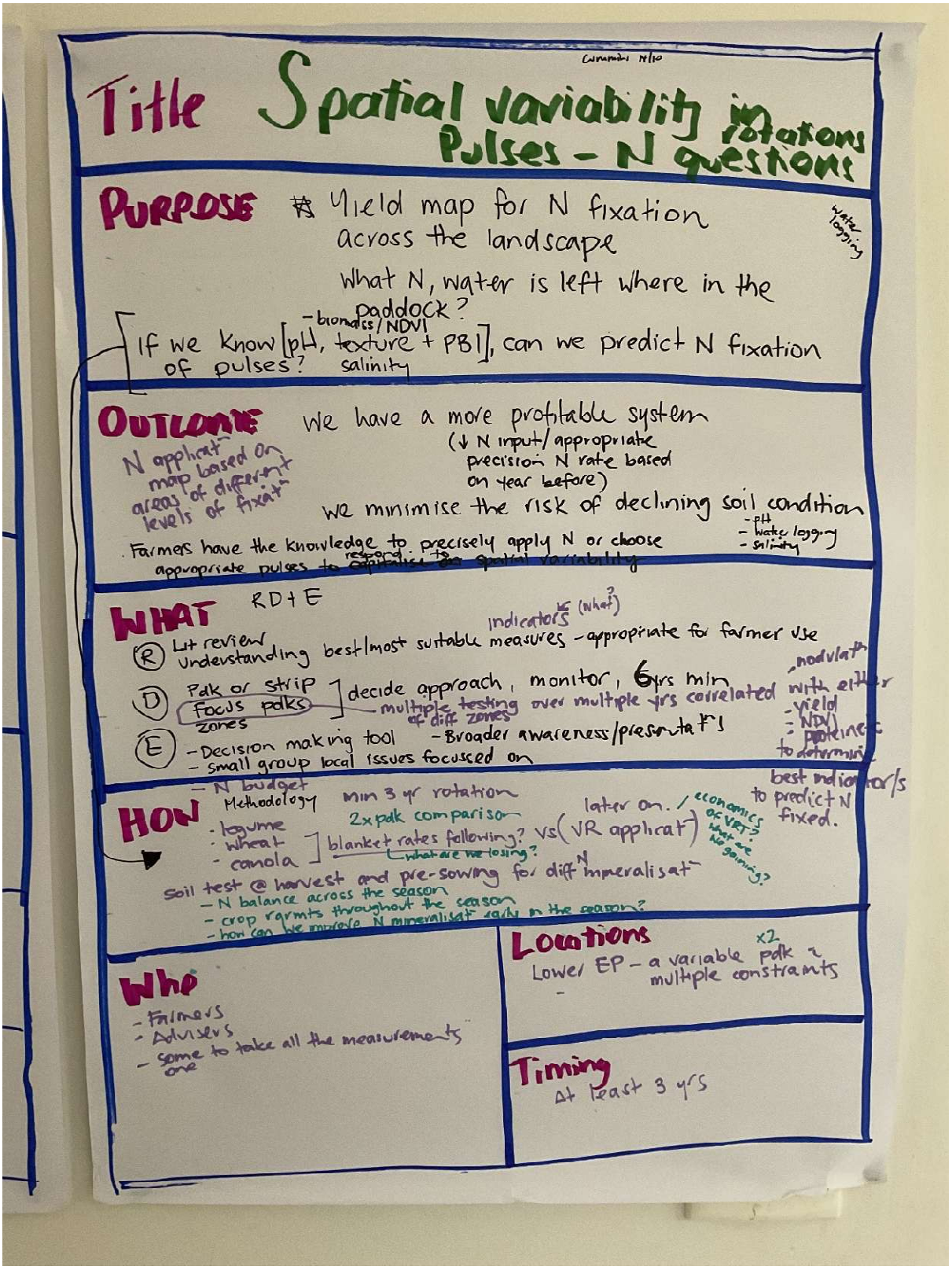
5. Water-Use Efficiency and Systems Data Gaps
    - Outdated WUE data, including pulse and canola CLLs and TEs
    - Regenerative farming — limited data to support scaling and adoption (R)

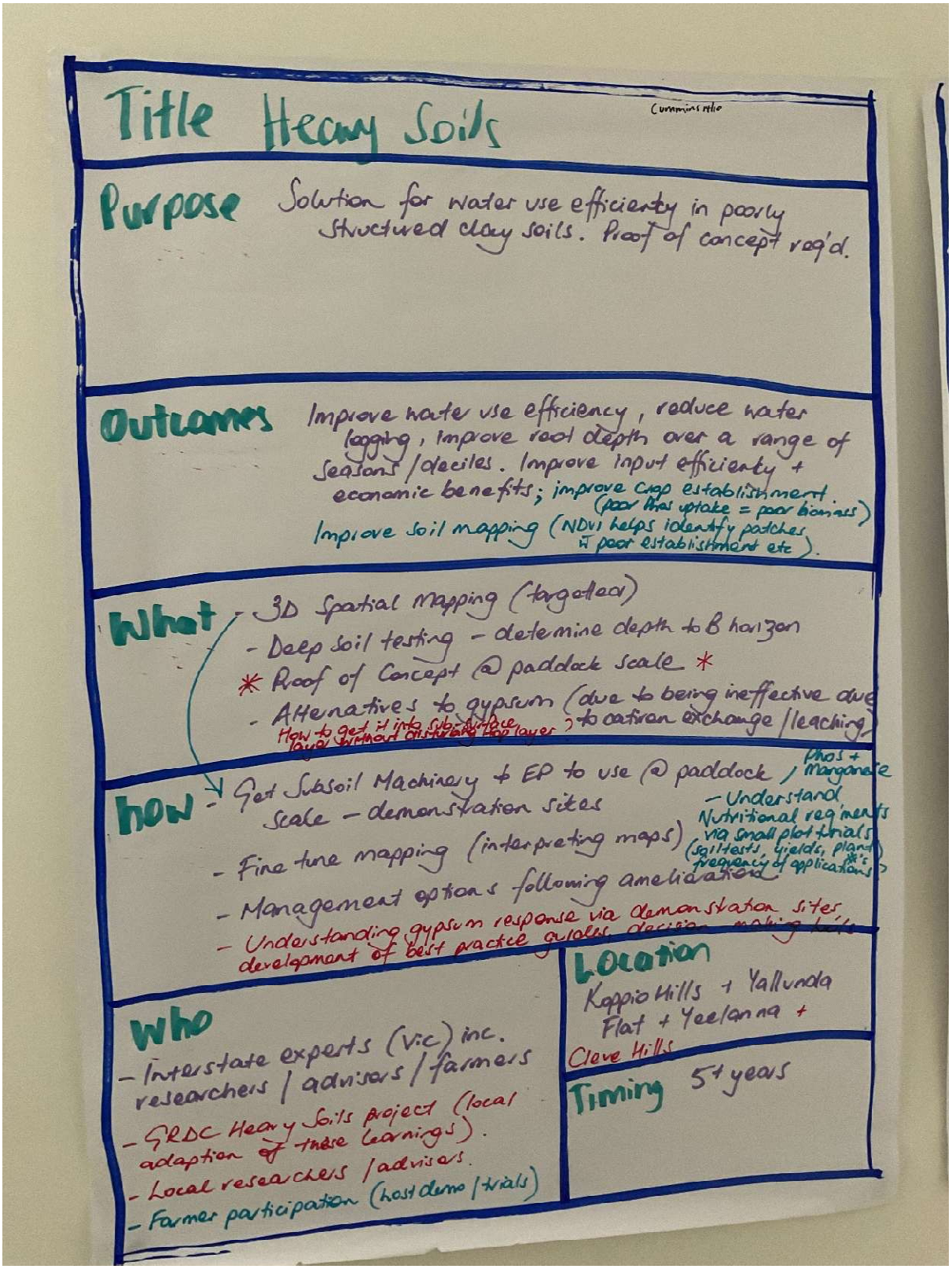
Appendix 6. Project Concepts

Wudinna – Capacity Building

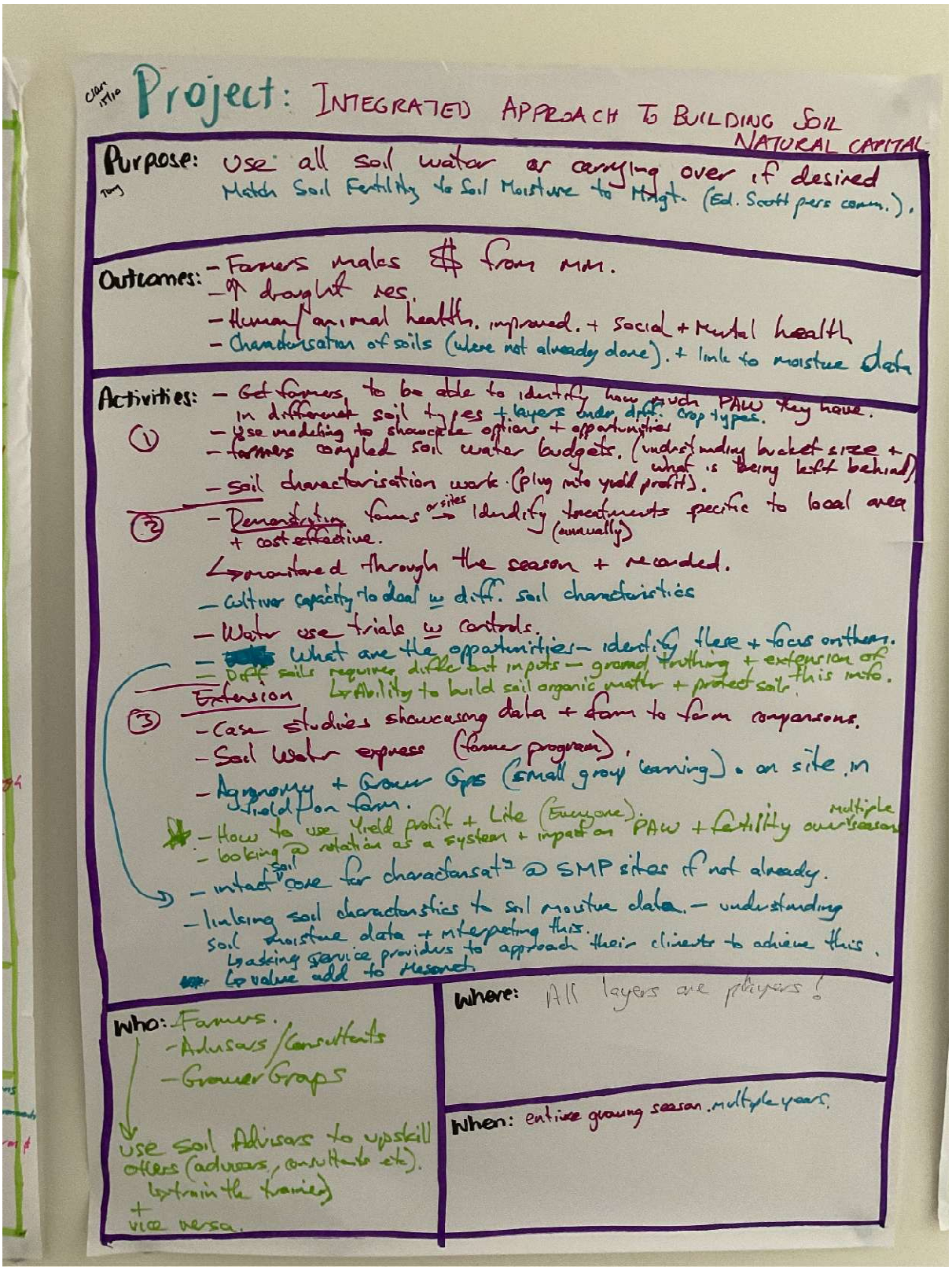



TITLE PA+ VRT FOR VARIABILITY
PURPOSE
"Evening the odds: Managing variable soils for consistent returns"
- economics, return on investment
- Best management across zones
- ID constraint @ the right time of season & quantify the action.
Outcomes
- quantify variability & manage at a scale thats useful.
- Improved digital mapping – constraints layers provide ability to make decisions.
- managing zone size for ROI
- Easy to id & apply
- Understanding where the reward for effort kicks in?
- Capacity building in our farmer & advisor community.
What
- Data layers ID, whats useful, remote & farmer collected. ✓
- Validation sites within zones (small plot) or demo size depending on zone size
- Long term data
- Intern based in PA on EP
- Support for on farm trials, farmer led.
- Yield x protein x NUE – water logging/use
How?
- ID largest constraint.
- One on one support.
- Process case study.
- Focus pairs } demo sites.
- Disc groups } ext.
- consolidate existing layers.
Who?
- Local consultants.
- SPAA
- PCT
- Laconic
- Sam T
- Local early adopters
Location
EP - Lower.
timing 5 yrs.

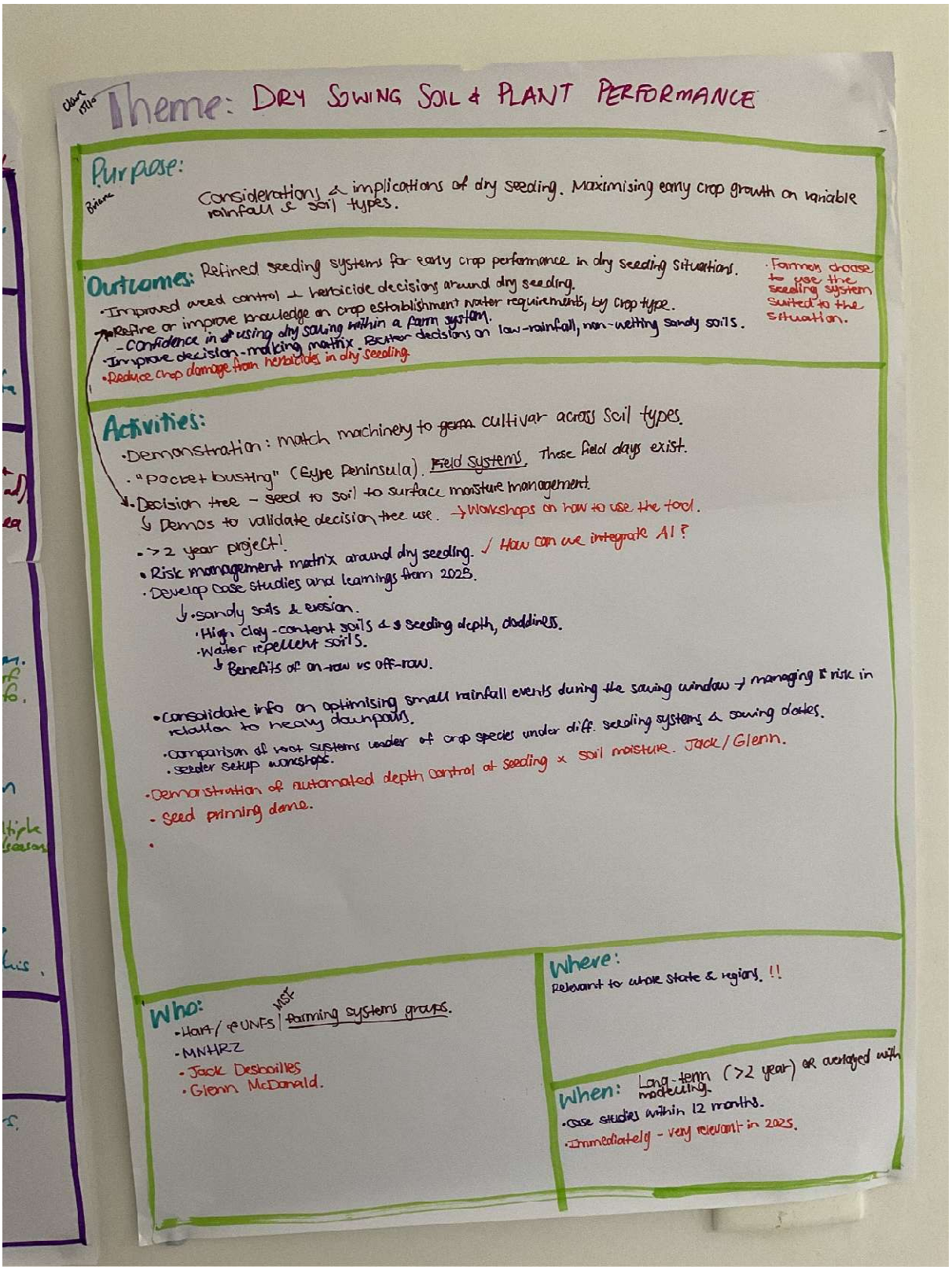

Title
Spatial variability in rotations
Pulses - N questions
PURPOSE
Yield map for N fixation across the landscape
What N, water is left where in the paddock?
If we know [pH, texture + PBI], can we predict N fixation of pulses?
- biomass / NDVI
salinity
OUTCOME
We have a more profitable system
(↓ N input/ appropriate precision N rate based on year before)
we minimise the risk of declining soil condition
- pH
- water logging
- salinity
Farmers have the knowledge to precisely apply N or choose appropriate pulses to
WHAT
RD+E
Lit review
Understanding
best/most suitable measures
indicators
- appropriate for farmer use
Pak or strip
Focus paks
zones
decide approach, monitor, 6yrs min
multiple testing of diff zones
over multiple yrs correlated
- Decision making tool
- Broader awareness/presentation
- small group local issues focussed on
HOW
- N budget
Methodology
min 3 yr rotation
2x pak comparison
- legume
- wheat
- canola
blanket rates following?
vs (VR applicat)
later on. / economics of VRT?
Soil test @ harvest and pre-sowing for diff N mineralisat
- N balance across the season
- crop rqrmts throughout the season
Who
- Farmers
- Advisers
- some one to take all the measurements
Locations
Lower EP - a variable pak
x2
multiple constraints
Timing
At least 3 yrs


Title Heavy Soils
Cummins title
Purpose
Solution for water use efficiency in poorly structured clay soils. Proof of concept req'd.
Outcomes
Improve water use efficiency, reduce water logging, improve root depth over a range of seasons/deciles. Improve input efficiency + economic benefits; improve crop establishment. (poor Nitrogen uptake = poor biomass)
Improve soil mapping (NDVI helps identify patches of poor establishment etc).
What
- 3D Spatial Mapping (targeted)
- Deep soil testing - determine depth to B horizon
* Proof of Concept @ paddock scale *
- Alternatives to gypsum (due to being ineffective due to cation exchange/leaching)
How to get it into subsurface layer without disturbing top layer?
How
- Get Subsoil Machinery + EP to use @ paddock / scale - demonstration sites
- Fine tune mapping (interpreting maps)
- Management options following amelioration
- Understanding gypsum response via demonstration sites
development of best practice guides decision making tools
- Understand Nutritional requirements via small plot trials (soil tests, yields, plant tissue tests, frequency of applications etc)
Phos + Manganese
Who
- Interstate experts (Vic) inc. researchers / advisors / farmers
- GRDC Heavy Soils project (local adaption of these learnings).
- Local researchers / advisors.
- Farmer participation (host demo / trials)
Location
Kappio Hills + Yallunda Flat + Yeelanna + Clove Hills
Timing
5+ years

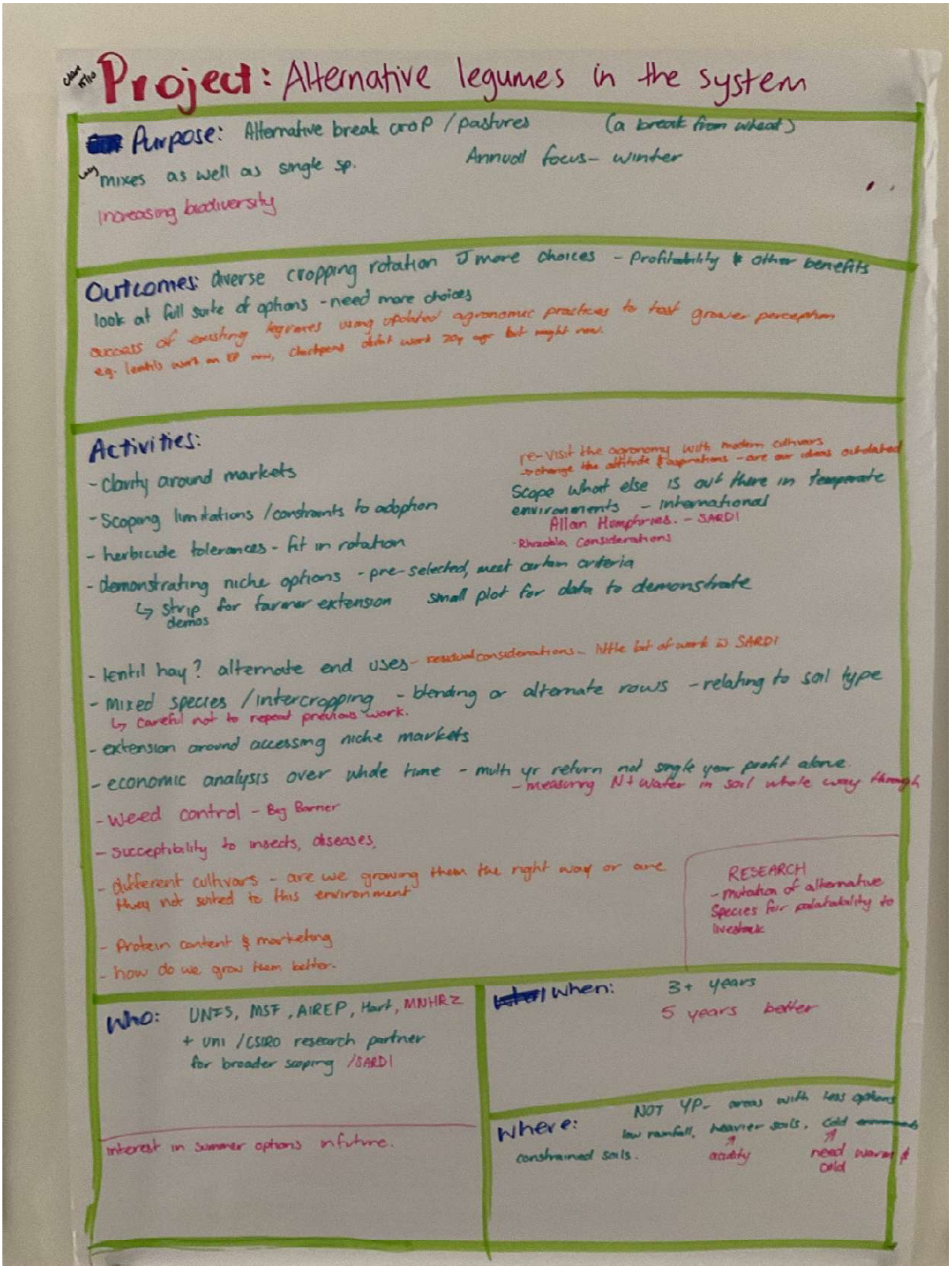
Clare – Soil natural capital

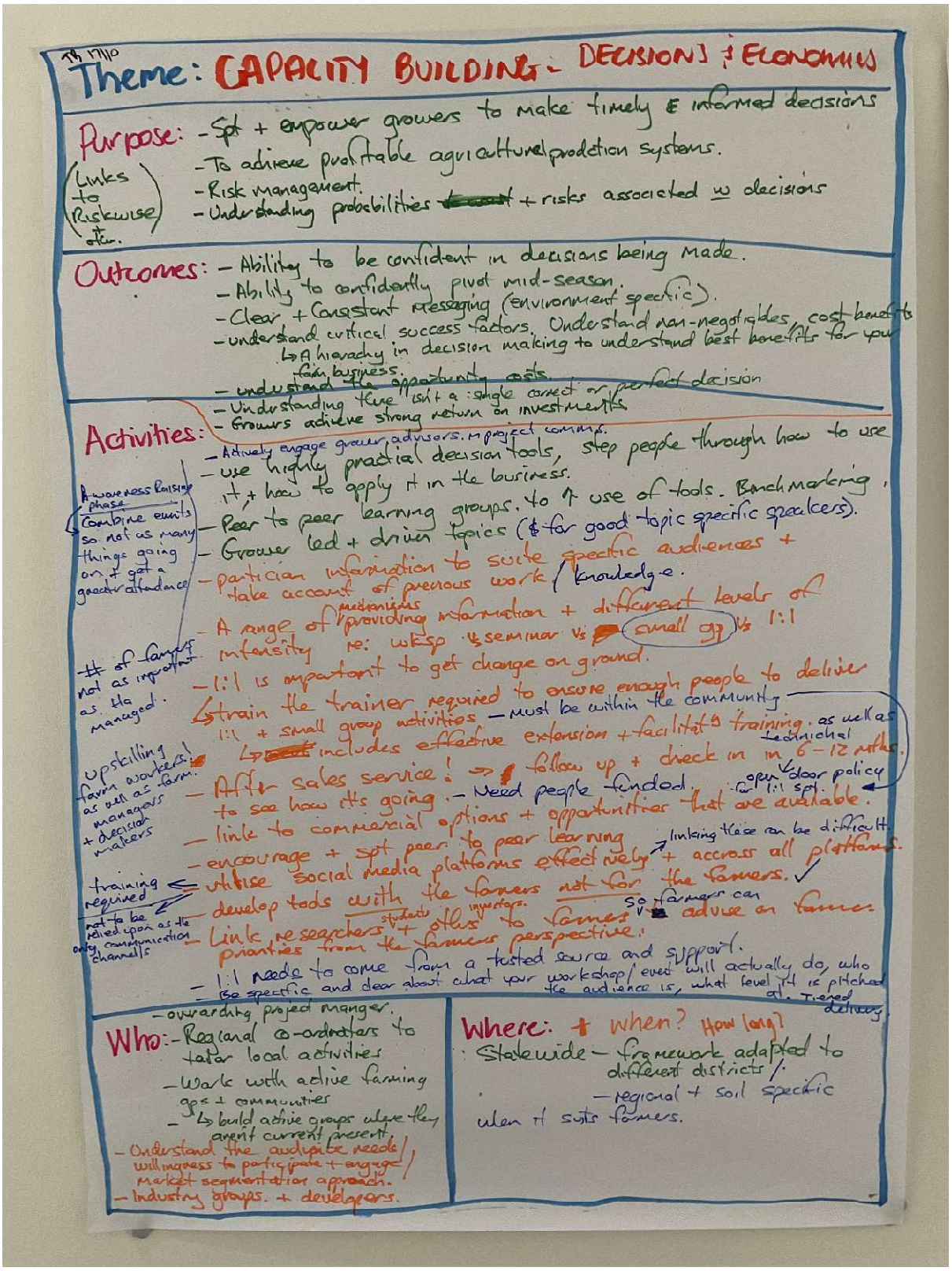


Clare – Dry Sowing

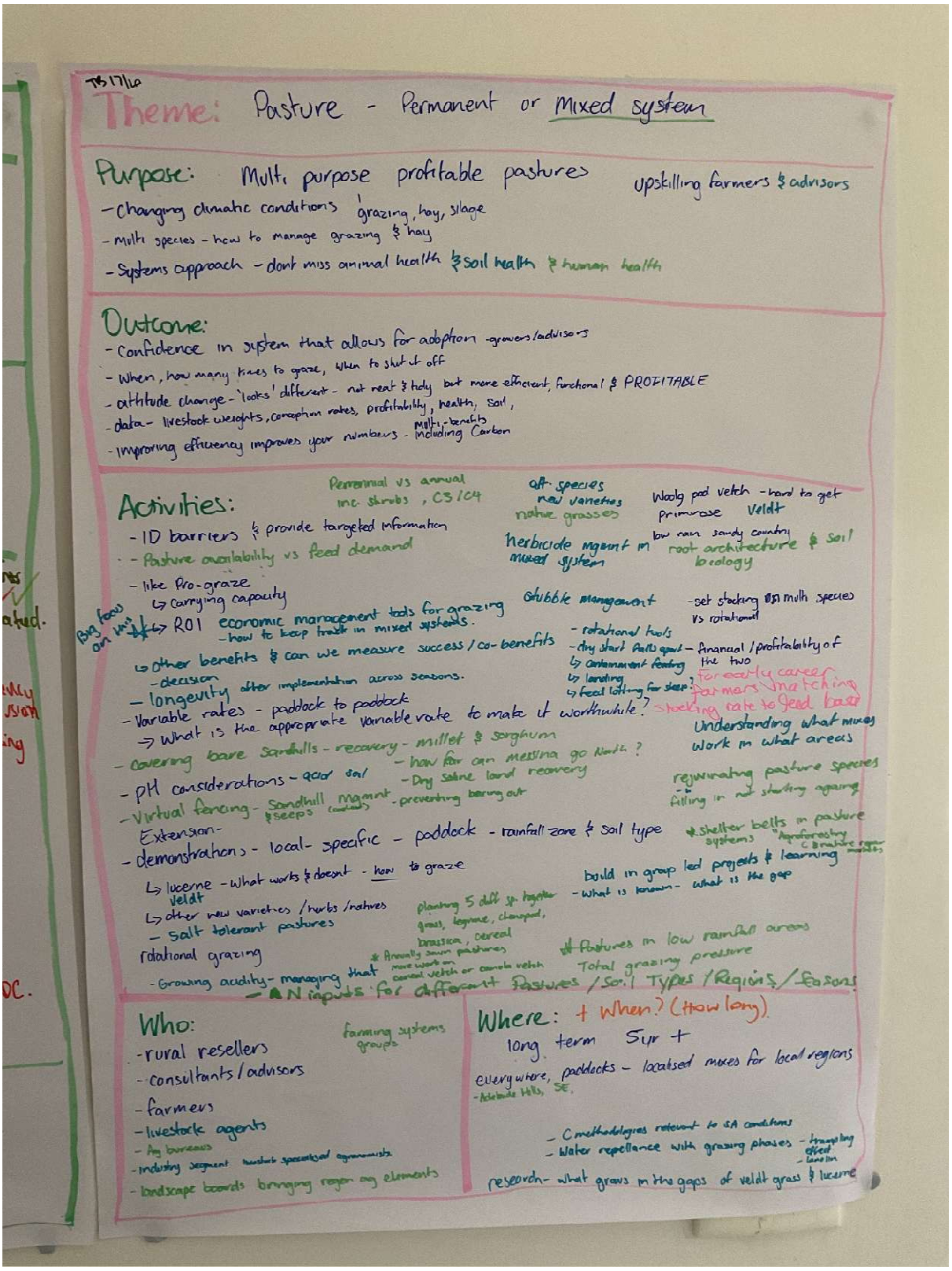


Clare – Alternative legumes

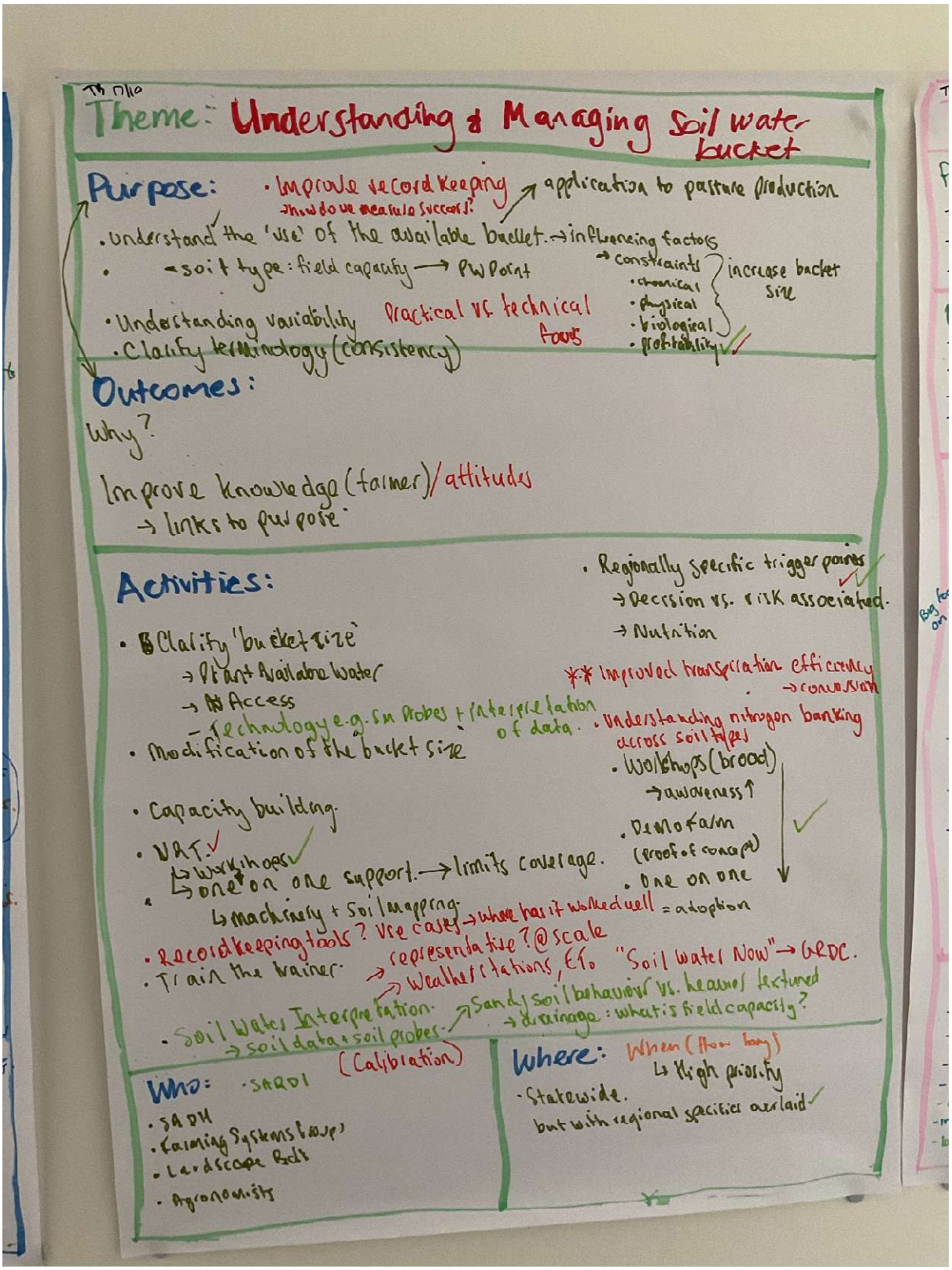



Theme: CAPACITY BUILDING - DECISIONS & ECONOMICS
Purpose:
- Spt + empower growers to make timely & informed decisions
- To achieve profitable agricultural prodction systems.
- Risk management.
- Understanding probabilities + risks associated w decisions
(Links to Riskwise etc.)
Outcomes:
- Ability to be confident in decisions being made.
- Ability to confidently pivot mid-season.
- Clear + Constant messaging (environment specific).
- understand critical success factors. Understand non-negotiables, cost benefits
- Understanding time isn't a single correct or perfect decision
- Growers achieve strong return on investments
Activities:
- Actively engage grower advisors. Project comms.
- use highly practical decision tools, step people through how to use it, + how to apply it in the business.
- Peer to peer learning groups. to ↑ use of tools. Benchmarking,
- Grower led + driven topics ($ for good topic specific speakers).
- particular information to suite specific audiences + take account of previous work / knowledge.
- A range of providing information + different levels of intensity re: wksp vs seminar vs small gp vs 1:1
- 1:1 is important to get change on ground.
- train the trainer required to ensure enough people to deliver 1:1 + small group activities - must be within the community
- includes effective extension + facilitation training, as well as technical
- After sales service! => follow up + check in in 6-12 mths. to see how it's going. - Need people funded. open door policy for 1:1 spt.
- link to commercial options + opportunities that are available.
- encourage + spt peer to peer learning
- utilise social media platforms effectively + across all platforms. linking these can be difficult.
- develop tools with the farmers not for the farmers.
- Link researchers + students + others to farmers so farmers can advise on farmers. investors.
priorities from the farmers perspective.
- 1:1 needs to come from a trusted source and support.
- Be specific and clear about what your workshop/ event will actually do, who the audience is, what level it is pitched at. Tiered delivery.
Awareness Raising phase
Combine events so not as many things going on, + get a greater attendance
# of farmers not as important as the managed.
Upskilling farm workers as well as farm managers + decision makers
training required
not to be relied upon as the only communication channels
Who:
- overarching project manager.
- Regional co-ordinators to tailor local activities
- Work with active farming grps + communities
- build active groups where they aren't current present.
- Understand the audiences needs/ willingness to participate + engage/ market segmentation approach.
- Industry groups. + developers.
Where: + When? How long?
Statewide - framework adapted to different districts/.
- regional + soil specific
when it suits farmers.

Tailem Bend - Pastures



Tailem Bend – Soil water bucket



ACKNOWLEDGEMENT

This project is supported by the South Australian Drought Resilience Adoption and Innovation Hub, through funding from the Australian Government's Future Drought Fund.

The SA Regional Soils Coordinator role is part of a national network of Regional Soils Coordinators (RSC), supported by the Australian Government through funding from the Climate-Smart Agriculture Program under the Natural Heritage Trust.



DISCLAIMER

Any recommendations, suggestions or opinions contained in these publications do not necessarily represent the policy or views of the South Australian Drought Resilience Adoption and Innovation Hub (SA Drought Hub). No person should act on the basis of the contents of these publications without first obtaining specific, independent, professional advice. The SA Drought Hub and contributors to these publications may identify products by proprietary or trade names to help readers identify particular types of products. The Hub does not endorse or recommend the products of any manufacturer referred to. Other products may perform as well as or better than those specifically referred to. The SA Drought Hub will not be liable for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information in these publications.