

## Curriculum Vitae – Dr Hayley Norman



Hayley Norman is an agricultural scientist who is passionate about helping industry achieve profitable and environmentally sustainable farming systems. After gaining a PhD in the reproductive ecology of annual legumes, Hayley moved to CSIRO in 2000 to conduct on-farm research in the sustainable management of saline land. She developed an interest in the use of drought and salt tolerant shrubs to improve both profitability and environmental outcomes within mixed farming systems. Hayley and her colleagues utilise systems modelling and on-farm research to identify plants and genotypes that have nutritional profiles that address key gaps within livestock feeding systems. They have developed novel methods to measure and predict feeding value of crops and forage, and routinely utilise the ‘nutritional wisdom’ of sheep to identify superior plants. Hayley’s work has a multidisciplinary focus and she collaborates with leading farmers, agronomists, hydrologists, livestock physiologists, economists and seed/tree suppliers. In developing plants and systems, Hayley utilises her expertise in farming systems, plant ecology, ruminant nutrition, near-infrared spectroscopy (NIRS), methods to quantify diet selection and measurement of livestock productivity. Her team are working with industry to develop national NIRS calibrations for all forage species within the Australian feedbase. Hayley utilises a participatory research framework with the aim of solving on-farm problems. She has worked with research agencies, universities, farmers and smallholders across southern Australia, Iraq, Syria, China (Tibet AR) and Afghanistan. Hayley enthusiastically supports emerging scientists and women in the workplace and actively mentors a number of people in CSIRO and other agencies. She chairs the WA Soil and Land Conservation Council (government advisory), is deputy chair of the WA Livestock Research Council and represents CSIRO on the WA Crawford Fund Committee. She is an associate editor for Grass and Forage Science (Journal of the British Grasslands Society).

### Education

BSc (Agric) Hons. University of Western Australia, 1995.  
PhD (with Distinction) University of Western Australia, 2002.  
Thesis titled ‘Reproductive Strategies of Annual Legumes from Arid Regions’  
Australian Company Directors Course

### Employment history

CSIRO	2019 - present	Senior Principal Research Scientist and Group Leader
	2014 - 2019	Principal Research Scientist & Team Leader
	2008 - 2014	Senior Research Scientist & Team Leader
	2001 - 2008	Postdoctoral and Research Scientist

### Research Interests

- Sustainable and profitable intensification of crop and livestock production within mixed farming systems.
- Management of climatic variability and salinity in landscapes with a focus on mitigating risk, improving environmental health and animal welfare.
- Novel methods to measure the nutritional value of forage plants within livestock production systems, diet selection and animal performance. Development of a broad NIRS calibrations to predict nutritional value of all pasture plants within the Australian feedbase. Ongoing development of NIRS to predict methane emissions and diet selection.
- Domestication and selection of shrubs and legumes with a focus on improving farm profitability through higher nutritional value, biomass production and relative palatability.
- Sustainable ruminant production systems for smallholders in saline, infertile and arid landscapes. Projects undertaken in Iraq, Pakistan, Afghanistan and the Tibetan Autonomous Region of China
- Seed dormancy and reproductive ecology of forage plants in dry environments with the aim of improving establishment and persistence within mixed farming systems.
- Improvement of soil health within farming and extensive grazing systems.

### Achievement and Awards

- Hayley has led or managed components of more than \$45M of collaborative, industry research projects in the past 18 years. Research co-funders include MLA, AWI, ACIAR, GRDC, DAFF, Land and Water Australia and DFAT.
- Hayley recognised high selectivity by sheep among native shrubs on saline land and linked preference to nutritional value. Improving feeding value of shrubs offered industry a win:win scenario as adoption of shrubs by producers for profitability would also leverage improved environmental outcomes. The team utilised systems modelling to identify the key limitations of woody shrubs (energy value) and developed a programme of work that led to the

commercialisation of Anameka™ saltbush in 2015. To date, more than 6 million shrubs have been planted by over 8500ha by 325 producers across Australia. These plants are now being investigated as an option to mitigate drought and improve reproductive outcomes through provision of antioxidants, shade and shelter. Hayley has commercialised another saltbush genotype 'SeaKiss' with Moojapin Foods.

- Hayley co-led a national project with the aim of developing NIRS calibrations to improve feed evaluation and animal growth predictions across Australia (MLA). To date, they have developed broad, multispecies NIRS calibrations that cover more than 130 forage species. Methods to provide accurate, rapid and inexpensive assessment of the nutritional values of feeds is critical to our ability to improve growth rates on farm and in feedlots. Her team collaborate with several plant development and breeding groups to assist them to identify plants with superior feeding value and capacity to reduce methane emissions.
- 2015, Hayley was shortlisted for an award in the Shell Australian Innovation Challenge
- 2013, she was a member of the 'Enrich' research team that was awarded the 2013 Eureka Science Award.

#### Postgraduate student supervision

- 2 Postdocs, 8 PhD, 4 Masters and 6 Honours students.

#### Leadership, Science and Professional Areas

- Since 2020, Group Leader for CSIRO Western Farming Systems (~20 FTE).
- Since 2021, WA Agricultural Research Collaboration, CSIRO lead Grains Transformation & Climate Resilience Programs.
- Since 2021, A&F Site Leader for Floreat, WA.
- Since 2019, Deputy Chair and Chair of the WA Soil and Land Conservation Council (Ministerial advisory council)
- Since 2021, member of the UWA Institute of Agriculture Advisory Board.
- Since 2018, WA Crawford Fund Committee.
- Since 2016, CSIRO representative and Deputy Chair of the WA Livestock Research Council.
- Since 2016, Associate Editor for Grass and Forage Science Journal (British Grasslands Society).
- 2021, Completed Australian Institute of Company Directors Course.
- 2012 - 2020 Adjunct Associate Professor, School of Plant Biology, University of WA.
- 2020, Co-editor of proceedings and organising committee of the Australian Association of Animal Sciences Conference.
- 2020, Co-editor of a special edition of Grass and Forage Science.
- 2014, organising committee of the International Ruminant Physiology Conference.
- Invitations to present research outcomes at 14 international forums and meetings

#### Publication and communication metrics

- Researcher ID: B-9808-2008
- 61 peer reviewed papers, 52 refereed conference publications, 6 invited international keynotes
- h-index of 19, >1260 citations (Web of Science)
- 6 television interviews, 38 rural extension articles/videos, 114 print media articles, 18 radio interviews and an international documentary (Planet Sand).

#### Current projects

- 'A transformational and integrated feedbase for meat production in the low to medium rainfall mixed farming zones of NSW and WA. MLA, CSIRO, DPIRD, Select Carbon. *We will conduct research to test four interventions to transform the feedbase and improve nutrient supply for sheep production. This includes more winter biomass, improved nutritional value through senescence, forage conservation and perennials to fill feed gaps.*
- 'HALO, harvestable annual legume options.' WA Agricultural Research Collaboration, Grains Transformation. Murdoch University, DPIRD, CSIRO. *This project will deliver a suite of commercial and affordable hard seeded pasture legumes well adapted to the WA environment and quantify the net methane, N and C benefits of adoption.*
- 'Design, composition and establishment of edible shelter for improved lamb survival.' MLA, Murdoch University, UWA, NSW DPI, University of Sydney. *The project will investigate the impacts of different types and designs of edible shelter on the physiology, behaviour, welfare and survival of sheep along with the nutritional benefits of the feedbase in mixed farming enterprises.*
- 'Too hot for ewe and me' MLA, Murdoch University, UWA, NSW DPI, University of Sydney. *The project aims to comprehensively quantify the effects of heat events on sheep reproduction, thermoregulatory capacity, behaviour, and wellbeing through long term data collection during a range of climatic conditions in diverse production settings.*

- 'Anameka shrub systems for drought resilient soils and landscapes.' CSIRO Drought Mission, DAFF Future Drought Fund, DPIRD, Select Carbon, Facey Group, Fitzgerald Biosphere Group. *The national project demonstrates the opportunity to use Anameka saltbush and elite forage legumes to reduce risk associated with drought.*
- 'Direct sowing Anameka saltbush to reduce establishment cost and accelerate the national adoption rate of saltbush forages for climate resilience' CSIRO Drought Mission project. *The project investigates the reproductive ecology of saltbush and investigates opportunities for paddock-scale establishment from seed.*

#### Projects successfully delivered.

- 'New generation NIRS calibrations to improve feed evaluation and animal growth predictions'. CSIRO, NSW DPI, MLA Livestock Productivity Partnership. (2019-2023). *The project developed broad, multispecies feed NIRS calibrations that meet current and future feed testing requirements for the Australian livestock industries. Faecal NIRS calibrations were developed to predict diet selection, intake and nutritional value of the diet.*
- 'No more gaps with superior shrub systems'. CSIRO, funded by MLA and AWI (2019-2023). *The team delivered high-value shrub systems to improve utilisation of the autumn feed base in Mediterranean and low rainfall mixed farming systems. Research was conducted to develop elite seed lines, test direct seeding methods and develop agronomic management packages.*
- 'Boosting profit and reducing risk on mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods (Dryland Pasture Legume Systems, 2018-2022). Hayley was part of a team that designed and delivered the \$16M Collaboration with DAFF, GRDC, MLA, AWI, Murdoch University, CSIRO, SARDI, NSW DPI and DPIRD. *This project developed novel annual pasture legumes for mixed systems in the low to medium rainfall zone. The aim was to increase adoption of pasture legumes, boosting average farm profit by 10% and halving the risk of financial losses.*
- ACIAR 'Developing profitable and nutritionally secure integrated crop-livestock enterprises in the middle altitude Himalayan valleys of Tibet' (2017-2020). *The aim was to increase household income and food security through more efficient livestock production and better access to markets.*
- 'Australian old man saltbush varieties for Pakistan'. With Murdoch University, funded by ACIAR and DFAT (2016 – 2019). *Anameka™ saltbush was successfully exported to the University of Agriculture in Faisalabad, ready for multiplication for future field trials. Anameka saltbush could play a significant role in management of saline and arid lands in Pakistan.*
- 'ACIAR Forage options for smallholder livestock in water-scarce environments of Afghanistan'. Collaborating with the International Centre for Agriculture in Dry Areas, Murdoch University and the Afghanistan Ministry of Agriculture (2014 – 2018). *The team compared a wide range of novel and imported forage genotypes to local landraces and identified several new options that are being upscaled. Hayley contributed saltbush for testing and worked with Afghan women to develop village-based saltbush production systems. The saltbush collaboration is ongoing.*
- 'Nitrate and sulphate rich shrubs to reduce methane and increase productivity'. Department of Agriculture Filling the Research Gap Project with Australian Wool Innovation and the University of WA (2013 – 2016). *We found that native shrubs can improve profitability and the relative benefits are largest in dry seasons. Grazing studies demonstrated that shrub systems extended the duration of liveweight maintenance over summer/autumn without grain supplements and access to saltbush resulted in a 20% increase in clean wool growth. Variation within and between shrubs indicated significant scope for plant improvement.*
- 'ELLE: Efficient livestock low emissions' (pasture species to reduce methane). Department of Agriculture Filling the Research Gap Project, led by UWA with SARDI, 2012 - 2015. *This project examined 110 species of forage plants, examining productivity, nutritional value and methane emissions. Hayley's team delivered evidence that it is possible to have a single NIRS calibration for all species in southern Australia.*
- 'Old man saltbush Improvement'. Funded by CRC Future Farm Industries with SARDI and NSW DPI. Completed May 2014, collaborating with several state agencies and producer groups. *Led to commercialisation of Anameka™ shrub*
- 'Salinity in Iraq'. ACIAR funding, with the International Centre for Agriculture in Dry Areas, UWA and various Iraqi Ministries and Universities. Successfully completed in 2013. *This project mapped salinity in the Tigris and Euphrates basin and identified options for productive use of saline land.*
- 'Enhance' and 'Enrich' projects – shrubs to improve productivity and animal health'. CSIRO, SARDI, UWA, funded by CRC Future Farm Industries, MLA and AWI. Successfully completed in May 2014. *Investigated the role of Australian native shrubs to improve resilience of farming systems and livestock productivity.*

- ‘Sustainable Grazing on Saline Lands WA1 and WA2’, funded by Land, Water and Wool, AWI, CSIRO, DAFWA. Completed in 2007. *These projects investigated use of saline land for livestock production and investigated the impact of shrubs on hydrological balance in discharge zones.*

### Selected peer reviewed scientific publications

- Norman HC, Masters DG** (2023). Livestock preference and feeding value as key determinants for forage improvement – why not ask the consumer? *Animal Production Science* (Online early)
- Masters DG, Blache D, Lockwood AL, Maloney SK, **Norman HC**, Refshauge G, Hancock SN (2023). Shelter and shade for grazing sheep: implications for animal welfare and production and for landscape health. *Animal Production Science* 63, 623-644.
- Monjardino M, Loi A, Thomas DT, Revell CK, Flohr BM, Llewellyn RS, **Norman HC** (2022). Improved legume pastures increase economic value, resilience and sustainability of crop-livestock systems. *Agricultural Systems* 203, 103519.
- Norman HC**, Humphries AW, Hulm E, Young P, Hughes SJ, Rowe T, Peck D and Vercoe PE (2021). Productivity and nutritional value of 20 species of perennial legumes in a low-rainfall Mediterranean-type environment in southern Australia. *Grass and Forage Science*, 76 (1), 134-158.
- Thomas DT, Flohr BM, Monjardino M, Loi A, Llewellyn RS, Lawes RA, **Norman HC** (2021) Grazing systems benefits from higher nutritive value of annual pasture legumes. *Agricultural Systems*. 194, 103272
- Norman HC**, Hulm E, Humphries AW, Hughes SJ, Vercoe PE (2020). Broad near infrared spectroscopy calibrations can predict the nutritional value of over one hundred forage species within the Australian feedbase. *Animal Production Science* 60, 1111-1122.
- Norman HC**, Cocks PS, Galwey NW (2020). Populations of two annual clovers species evolved in response to 13 years of grazing management and phosphate fertiliser application. *Grass and Forage Science* 75, 64-75.
- Masters DG, **Norman HC** and Thomas DT (2019). Minerals in pastures—are we meeting the needs of livestock? *Crop & Pasture Science*. 70, 1184-1195.
- Norman HC**, Duncan EG and Masters DG (2019). Halophytic shrubs accumulate minerals associated with antioxidant pathways. *Grass and Forage Science* 74, 345-355.
- Norman HC**, Hulm E, Wilmot MG (2016). Improving the feeding value of old man saltbush for saline production systems in Australia. In: Halophytic and Salt tolerant Feedstuffs: Impacts on Nutrition, Physiology and Reproduction of Livestock (Eds. El Shaer HM; Squires VR) pp 79-86.
- Li X, **Norman HC**, Kinley R, Laurence M, Wilmot M, Bender H, de Nys R and Tomkins N (2016). Inclusions of *Asparagopsis taxiformis* in the diet of sheep decreases enteric methane production. *Animal Production Science*, 58, 681-688.
- Barrett-Lennard EG, **Norman HC**, Dixon K (2016). Improving saltland revegetation through understanding the "recruitment niche": potential lessons for ecological restoration in extreme environments. *Restoration Ecology* 24, S91-S97.
- Amanoel DE, Thomas DT, Blache D, Milton JTB, Wilmot MG, Revell DK, **Norman HC** (2016). Sheep deficient in vitamin E preferentially select for a feed with a higher concentration of vitamin E. *Animal* 10, 183-191.
- Revell DK, **Norman HC**, Vercoe PE, Phillips N, Toovey A, Bickell S, Hulm E, Hughes S, Emms J (2013). Australian perennial shrub species add value to the feed base of grazing livestock in low- to medium-rainfall zones. *Animal Production Science* 53, 1221-1230.
- Norman HC**, Cocks PS, Galwey NW (2010). Influence of stocking rate and phosphate fertiliser application on the composition of annual legume seedbanks within a Mediterranean grassland. *Crop & Pasture Science* 61, 988-1000.
- Ben Salem H, **Norman HC**, Nefzaoui A, Mayberry DE, Pearce KL, Revell DK (2010). Potential use of oldman saltbush (*Atriplex nummularia*) Pearce KL, **Norman HC**, Hopkins DL (2010). The role of saltbush-based pasture systems for the production of high quality sheep and goat meat. *Small Ruminant Research*, 91, 29-38.
- Norman HC**, Wilmot MG, Thomas DT, Masters DG, Revell DK (2009). Stable carbon isotopes accurately predict diet selection by sheep fed mixtures of C-3 annual pastures and saltbush or C-4 perennial grasses. *Livestock Science* 121, 162-172.
- Masters DG, Benes SE, **Norman HC** (2007). Biosaline agriculture for forage and livestock production. *Agriculture Ecosystems & Environment* 119, 234-248.
- Norman HC**, Smith FP, Nichols PGH, Si P, Galwey NW (2006). Variation in seed softening patterns and impact of seed production environment on hardseededness in early-maturing genotypes of subterranean clover. *Australian Journal of Agricultural Research* 57, 65-74.
- Norman HC**, Cocks PS, Galwey NW (2005). Annual clovers (*Trifolium* spp.) have different reproductive strategies to achieve persistence in Mediterranean-type climates. *Australian Journal of Agricultural Research* 56, 33-43.
- Norman HC**, Freind C, Masters DG, Rintoul AJ, Dynes RA, Williams IH (2004). Variation within and between two saltbush species in plant composition and subsequent selection by sheep. *Australian Journal of Agricultural Research* 55, 999-1007.
- Norman HC**, Galwey NW, Cocks PS (2002b). Hardseededness in annual clovers: variation within populations and subsequent shifts due to environmental changes. *Australian Journal of Agricultural Research* 53, 831-836.
- Norman HC**, Cocks PS, Smith FP, Nutt BJ (1998). Reproductive strategies in Mediterranean annual clovers: germination and hardseededness. *Australian Journal of Agricultural Research* 49, 973-982.