Estimating Recharge from Alley Farms
Applying the ENOR model within the Murray-Darling Basin

SUMMARY DOCUMENT

Tim Ellis, Yves Bessard and Jim Brophy

CSIRO Land and Water
Technical Report 3/01, April 2001
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Alley farming

Alley farming is an agroforestry system that comprises belts of trees and or shrubs, alternated across the landscape with strips of crop or pasture. This system was originally developed for a tropical landscape to promote a diversification of plant species in the production system and also to help stabilise steep slopes. Over the last decade, there has been a significant level of interest in alley farming from Australian farmer groups for whom it offers solutions to a range of problems including wind erosion, lack of stock shelter and rising water tables.

How to use this report

This document is a summary of the CSIRO Land and Water Technical Report (Ellis et al., 2001). It is a procedure for estimating the relative recharge, and/or actual recharge from mature alley farms in the Murray Darling Basin if they were used to replace conventional farming systems. It can be applied to existing or hypothetical alley farms. Alternatively, an alley farm can be designed to achieve a ‘target’ average recharge. The inputs required in both cases are:

1. Lineal Leaf Area $LLA$ of the tree belt(s) where Lineal leaf area (m$^2$ m$^{-1}$) of a belt of trees is equal to the leaf area (m$^2$) per unit length (m) of belt;
2. Leaf Area Index $LAI$ of natural vegetation where Leaf area index (m$^2$ m$^{-2}$) of a block of vegetation is equal to the ratio of plant leaf area (m$^2$) to the ground area (m$^2$) it covers;
3. The centre-to-centre belt spacing of the alley farm $W$.
4. An estimate of recharge from the conventional farming system $RC$.

If data is not available, this report can be used to estimate $LLA$, $LAI$ and $W$. If users choose to measure, rather than estimate $LLA$ and $LAI$, the methods for doing so are described in (Ellis et al., 2001). If $RC$ is not known typical values are available from Petheram et al. (2000).

Likely errors are described in the last section. The uncertainty associated with the recharge prediction will be higher if inputs are estimated, and should be kept in mind when using predictions. Other limitations to the application of the model are covered in detail in Ellis et al. (2001).
The model

Recharge from an alley farm is expressed as Relative Recharge $RR$

$$RR = \frac{\text{recharge from alley farm}}{\text{recharge from conventional farm}} = 1 - \frac{B}{W}$$

(1)

where $B$ is the Equivalent No Recharge (ENOR) width of the tree belts (m) and $W$ is the centre-to-centre spacing of the tree belts (m).

Figure 1: $ENOR$ width $B$ and belt spacing $W$ for an alley farm.

$B$ can be calculated from leaf area measurements

$$B = \frac{LLA}{LAI}$$

(2)

Where: $B$ is the width (Figure 1) of the $ENOR$ (m); $LLA$ is the Lineal Leaf Area of the tree belt ($m^2 m^{-1}$ belt).

If the magnitude of recharge from the conventional farming system $RC$ is known, an average recharge from the alley farm $RA$ can be calculated

$$RA = RC \times RR$$

(3)

Estimating inputs

Lineal Leaf Area of tree belt $LLA$

The scarcity of alley farms and appropriately sited tree belts for measurement will, in many cases, necessitate the estimation of $LLA$. Estimates can be made by inspecting the appended photographs of typical tree belts and deciding on an $LLA$ rank and range.

- small: $5 – 15 \text{ m}^2 \text{ m}^{-1}$;
- medium $16 – 30 \text{ m}^2 \text{ m}^{-1}$;
- large $31 – 45 \text{ m}^2 \text{ m}^{-1}$;
- very large $46 – 65 \text{ m}^2 \text{ m}^{-1}$;
- extremely large $>66 \text{ m}^2 \text{ m}^{-1}$.
Note: the rank refers to the magnitude of the LLA, not the physical dimensions of the trees. If more information is required on the tree belts, site details are tabulated in Ellis et al. (2001).

**Leaf Area Index of natural vegetation LAI**

LAI can be estimated for a site using Equation 4 if the long-term average annual rainfall $P$ and pan evaporation $E_0$ is known (Ellis et al., 1999).

$$
LAI = 2.9 \frac{P}{E_0}
$$

(4)

$P$ and $E_0$ can be obtained from the Australian Bureau of Meteorology weather maps. Alternatively, LAI can be estimated from the map (Figure 2) which was generated using Equation 4.

![Figure 2 Map of the Murray Darling Basin showing estimated Leaf Area Index LAI for natural vegetation.](image)
**Belt spacing W**

W is the centre-to-centre spacing of tree belts (Figure 1). If this measurement is not available from an existing site, typical values are between 50 m and 200 m. Usually this dimension is determined as a multiple of the width of the farmer’s seeding and/or harvesting machinery.

**Calculating recharge from an alley farm**

1. Estimate LLA for belt from appended photographs of example tree belts;
2. Estimate local LAI (Figure 2 or Equation 3);
3. Calculate B (Equation 2);
   \[ B = \frac{LLA}{LAI} \]
4. Choose centre-to-centre belts spacing W and calculate the percentage recharge reduction RR (Figure 1, Equation 1);
   \[ RR = 1 - \frac{B}{W} \]
5. Calculate average recharge RA from the alley farm (Equation 4);
   \[ RA = RR \times RC \]

**Example 1**

An alley farm is to be planted in a cropping paddock near Wagga Wagga (35°10′S 147°30′E). The farmer uses 10 m wide seeding equipment and wants to be able to sow the crop between the belts with 4 passes of the seeder. Assume tree belts will be 10 m wide, therefore the centre-to-centre spacing of the belts W would be 50 m. What relative recharge RR can be expected once the belts have matured? What will be the average recharge RA from the alley farm where recharge without tree belts RC is 50 mm yr\(^{-1}\)?

1. Choose a medium belt (see appended photographs) with an LLA = 20 m\(^2\) m\(^{-1}\);
2. Using Figure 2 estimate local LAI = 1.0;
3. Using Equation 2 calculate \[ B = \frac{20}{1} = 20 \text{ m} \]
4. Using Equation 1 calculate relative recharge \[ RR = 1 - \frac{20}{50} = 0.6 \]
5. Using Equation 3 \[ RA = 0.6 \times 50 = 30 \text{ mm yr}^{-1} \]

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**Designing an alley farm to meet a recharge target**

To design an alley system that will result in a prescribed recharge reduction, steps 1 to 3 are followed in the same way as above but Equation 3 in step 4 is solved for W rather than RR.
Example 2

If *E. cladocaylix* is intended for use in an alley farm at Albury (36°00′S, 147°00′E), what centre-to-centre belt spacing *W* would be required to reduce recharge to 20% of that from the conventional farming system? What proportion of the paddock would be left for crop or pasture production?

1. Estimate *LLA* = 40 m² m⁻¹, similar to Site 25, belts 4 m wide;
2. From Figure 2, *LAI* = 1.3 at Albury;
3. Calculate \( B = \frac{40}{1.3} = 31 \text{ m} \);
4. Rearrange Equation 1 and calculate \( W = \frac{B}{1-RR} = \frac{31}{1-0.2} = 39 \text{ m} \).
5. If the tree belts were 4 m wide then the proportion of the paddock remaining for crop and pasture would be \( \frac{39-4}{39} = 0.9 \).

If recharge from a cropping paddock at Albury is to be reduced by 80% using 4 m wide sugar gum (*E. cladocaylix*) belts, the belts would need to be placed every 39 m (measured centre-to-centre) across the paddock. The tree belts would occupy about 10% of the total land area.

Errors

A detailed error analysis (unpublished data) has shown that a maximum error of about 20% can be expected when estimating *B*, and hence *RR*, from field measurements of *LLA* and *LAI*.

Additional uncertainty is introduced if *LLA* and *LAI* are estimated, rather than measured. In reality, *LLA* will depend upon: tree species; growth stage; climate; site conditions; belt width; and cultural practice. *LLA* values measured from the appended example sites are therefore only a guide. Until better data sets and predictive tree belt growth models are available, we could expect error in estimating *LLA* to be as high as 50% but it is impossible to quantify. Ellis *et al.* (1999) give a standard error (S.E.yx) of ±0.4 for *LAI* estimated from the climate index (Equation 4, Figure 2). The total error possible for *B* could therefore be up to 90%. The prediction made in Example 1 (above) therefore would be *RA* = 30 ±27 mm yr⁻¹, although this is the maximum likely error.
Further reading


PMSEIC (1999) Dryland salinity and its impact on rural industries and the landscape, Prime Minister’s Science, Engineering and innovation Council Occasional Paper No. 1, Department of Industry, Science and resources, Canberra.


Acknowledgements

This work was funded by the Murray Darling Basin Commission (MDBC) as part of the Low Rainfall Alley Farming (LRAF) project, research project No. D9005 (MDBC, 2000) led by John Bourne, Primary Industries and Resources South Australia (PIRSA).

The authors and technicians worked from CSIRO Land and Water laboratories, Canberra.

We also thank the following people for their contribution to this study:

Ray Evans and Brian Myers for valuable advice and contacts with regard to the targeting of catchments for site selection. Additional contacts were supplied by the Murrumbidgee Landcare Association and the Murrumbidgee Catchment Management Committee.

The following landholders for granting access to their properties for data collection: The Bulle family; O.C’ and D.E. Killalea; W. Anderson; N. Boyer; H. Friend; P. O’Connor; N. Passelaqua; A. Hart; G. C. and R. Davis; W. Esler; D. and L. Kohlhegen; H. Sharkie; D. Daniels; and B. and R. Ross.

Rachelle Nevin, James Margules and Daniel Figucio for their assistance with data collection.

Andrew Bradford and Mat Gilfedder for GIS and graphics support.

Peter Hairsine for supervision of the project as well as operational and scientific advice and critical appraisal of this report. Peter also played an essential role in communications between the CSIRO, the MDBC and PIRSA.
Typical tree belts and LLA measurements

The purpose of the photographs and accompanying LLA measurements is to provide an appreciation of the likely range of LLA of tree belts and to allow an estimation of LLA for hypothetical tree belts/alley farms. Readers should note the following:

- Belt widths were measured stem to stem. Where the belt is a single row of trees, no belt width is given.
- Additional site details and tree dimensions can be found in Table 1, Ellis et al. (2001).
- Sites are numbered 1 to 27 and have been sorted in order of increasing climate wetness (P/Eo) which roughly corresponds with increasing local LAI.
- Unless otherwise specified, the following site photographs were taken at the time of measurement – between May and September 2000.
- To give an appreciation of scale, operators in the photographs are holding a staff 4 m long.
- Photograph captions include: species; type, orientation and location of planting.
- The LLA (m² m⁻¹) of each site is given and ranked: 5 – 15 small; 16 – 30 medium; 31 – 45 large; 46 – 65 very large; >66 extremely large. Note that the rank refers to the magnitude of the LLA, not the physical dimensions of the trees.

Site 1 Remnant E. socialis north-south oriented fence line planting at “Cooinya” south east of Kimba, SA. November 1998.

Belt width = 7 m.

LLA = 11 m² m⁻¹ – small.
Site 2 Remnant *E. dumosa* north-south oriented fence line at the Wakefield’s property near Walpeup, Vic. October 1997.

Belt width = 8 m.

$LLA = 25 \text{ m}^2 \text{ m}^{-1}$ – medium.

Site 3. *Atriplex nummulariai* and *Atriplex amnicola* north-south oriented alley farm trial at the Mallee Research Station, Walpeup, SA.

Belt width = 10 m.

$LLA = 13 \text{ m}^2 \text{ m}^{-1}$ – small.
Site 4 *Atriplex nummularia* and *Acacia saligna* north-south oriented alley farm trial at Pallamana, north of Murray Bridge, SA.

Belt width = 6 m.

$LLA = 42 \text{ m}^2 \text{ m}^{-1}$ – large.

Site 5 *E. leucoxylon* and *E. occidentalis* north-south oriented windbreak on the Selleck’s property near Roseworthy, SA.

Belt width = 4 m.

$LLA = 17 \text{ m}^2 \text{ m}^{-1}$ – medium.
Site 6 *E. maculata* belt in a north west-south east oriented alley layout at “Avondale”, Sandigo south east of Narrandra, NSW. The belt is one of several (see site 7) planted in an effort to reduce a saline seep a few kilometres away.

Belt width = 8 m.

$LLA = 22 \text{ m}^2 \text{ m}^{-1}$ – medium.

Site 7. *camaldulensis* (right) belt in a north west-south east oriented alley layout at “Avondale”, Sandigo south east of Narrandra, NSW. Site 6 can be seen on the far left.

Belt width = 8.5 m.

$LLA = 16 \text{ m}^2 \text{ m}^{-1}$ – medium.
Site 8 *E. cladocalyx* north-south fence line planting at “Avondale”, Sandigo south east of Narrandra, NSW.

Single row.

$LLA = 19 \text{ m}^2 \text{ m}^{-1}$ – medium.

Site 9 *E. leucoxylon, E. camaldulensis, E. maculata, E. micropcarpa, Acacia salicina* north-south oriented alley farm trial at Bridgewater-on-Loddon, near Bendigo, Vic.

Belt width = 10 m.

$LLA = 14 \text{ m}^2 \text{ m}^{-1}$ – small.
Site 10 *E. polybractia* (blue mallee) 18 mth old regrowth following harvest in a north-south oriented oil mallee plantation at “Tumbledown” south of West Wyalong, NSW.

Rows are 3 m apart.

\[ LLA = 5 \text{ m}^2 \text{ m}^{-1} \] – very small.

Site 11 *E. dawsioni* and *E. dwyleri* north-south fence line planting at “Truro” east of Wagga Wagga, NSW.

Belt width = 3 m.

\[ LLA = 15 \text{ m}^2 \text{ m}^{-1} \] – small.
Site 12 Belt of an unidentified eucalypt species in a north-south oriented wide-spaced alley (200 m between belts) at “Waerawi”, west of Old Junee, NSW.

Belt width = 3 m.

$LLA = 11 \text{ m}^2 \text{ m}^{-1}$ – small.

Site 13 $E. \text{sideroxylon}$ north-south oriented fence line planting at “Carinya”, west of Old Junee, NSW.

Belt width = 4 m.

$LLA = 14 \text{ m}^2 \text{ m}^{-1}$ – small.
Site 14 *E. microcarpa* north-south oriented fence line planting at Temora Research Station, north of Temora, NSW.

Single row.

$LLA = 17 \text{ m}^2 \text{ m}^{-1}$ – medium.

Site 15 *E. largiflorans* northeast-southwest oriented fence line planting at Temora Research Station, north of Temora, NSW.

Single row.

$LLA = 16 \text{ m}^2 \text{ m}^{-1}$ – medium.
Site 16 *E. saligna* and *E. botrioides* east-west windbreak at “Jayfields” north of Holbrook, NSW.

Belt width = 11 m.

\[ LLA = 54 \text{ m}^2 \text{ m}^{-1} \] – very large.

Site 17 *E. polyanthemos* remnant belt on a north-south fence line at “Ardrossan”, south east of Holbrook, NSW.

Belt width = 8 m.

\[ LLA = 25 \text{ m}^2 \text{ m}^{-1} \] – medium.
Site 18 *E. melliodora* and *E. sideroxylon* north-south oriented row, planted for stock shelter at “Killandaye” south east of Holbrook, NSW.

Single row.

\[ LLA = 24 \text{ m}^2 \text{ m}^{-1} \] – medium.

Site 19 *E. melliodora* north-south oriented row planted for stock shelter at “Killandaye” south east of Holbrook, NSW.

Single row.

\[ LLA = 24 \text{ m}^2 \text{ m}^{-1} \] – medium.
Site 20 *E. melliodora* and *E. globulus* north-south windbreak at “Mima” north of Holbrook, NSW.

Belt width = 9 m.

$LLA = 62 \text{ m}^2 \text{ m}^{-1}$ – very large.

Site 21 *E. melliodora* and *E. cladocalyx* north-south windbreak at “Mima” north of Holbrook, NSW.

Belt width = 9 m.

$LLA = 19 \text{ m}^2 \text{ m}^{-1}$ – medium.
Site 22 *E. albens*, *E. mannifera* and *E. dives* remnant windbreak oriented east-west at “Highfields”, west of Rosewood NSW.

Belt width = 16 m.

$LLA = 102 \text{ m}^2 \text{ m}^{-1}$ – extremely large.

Site 23 *E. globulus* council planting oriented north-south, east of Harden, NSW.

Single row.

$LLA = 29 \text{ m}^2 \text{ m}^{-1}$ – medium.
Site 24 *E. camaldulensis* discharge planting (valley floor seep) oriented north-south at “Oxton Park”, northwest of Harden, NSW.

Belt width = 12 m.

*LLA* = 16 m² m⁻¹ – medium.

Site 25 *E. globulus* council planting, oriented north-south at Chifley, ACT. Photographed December 2000.

Belt width = 4 m.

*LLA* = 45 m² m⁻¹ – large.
Site 26 *E. globulus* east-west oriented fence line planting at “Emu Flat” north of Yass, NSW.

Single row.

$LLA = 17 \text{ m}^2 \text{ m}^{-1}$ – medium.

Site 27 *E. camaldulensis* east-west oriented windbreak at “Bobbara Creek” west of Binalong, NSW. There was significant insect leaf damage.

Belt width = 6 m.

$LLA = 7 \text{ m}^2 \text{ m}^{-1}$ – small.