



Jul 1st, 12:00 AM

PlanIT : a multiuser 4D decision support tool for land and water resource planning.

P. W. Holyland

Follow this and additional works at: <https://scholarsarchive.byu.edu/iemssconference>

Holyland, P. W., "PlanIT : a multiuser 4D decision support tool for land and water resource planning." (2002). *International Congress on Environmental Modelling and Software*. 201.

<https://scholarsarchive.byu.edu/iemssconference/2002/all/201>

This Event is brought to you for free and open access by the Civil and Environmental Engineering at BYU ScholarsArchive. It has been accepted for inclusion in International Congress on Environmental Modelling and Software by an authorized administrator of BYU ScholarsArchive. For more information, please contact scholarsarchive@byu.edu, ellen_amatangelo@byu.edu.

PlanIT : a multiuser 4D decision support tool for land and water resource planning.

P.W. Holyland

E-mail: peter@georeality.com

Georeality Pty Ltd, Suite 35, Lvl 8, 445 Upper Edward Street, Brisbane, Queensland, Australia 4004

Abstract: PlanIT is a PC based decision support system (DSS) designed for end users from farmers to government agencies. It is designed to be a generic multi-user platform to integrate biophysical, economic, and social data and models in a user friendly format. The user interface is a 4D world, showing photos of the farm or catchment draped over terrain, that can vary through time. The software allows for mapping, and editing both natural and man-made objects within the landscape. The user can visualise, analyse, simulate, and cost land management options including building dams, digging drains, fencing, choosing crops, revegetating, and applying pesticide etc. Market and climate forecasts can be input to allow managers of natural resources (farmers, agencies, developers, financiers) to explore what-if scenarios and arrive at decisions that optimise both the profitability of the enterprise and sustainability of the resource. The DSS matrix can be edited to allow for weighting of preferred outcomes.

The background software “engines” include a standard games engine linked to biophysical simulation models, cost-benefit analysis software, a multi-objective decision support tool, and market and climate historical and forecast data. Outputs include standard environmental, financial statement, and social decision outcomes.

Keywords: decision support system; games engine; resource planning.

1. INTRODUCTION

Many areas in the wheat belt of Western Australia are suffering the effects of waterlogging and salinity. A software management tool (PlanIT) has been developed over the past four years, which simulates surface water management; helps determine areas that are presently contributing to the degradation issues within catchments; and models options to limit the degradation. The tool also integrates cost-benefit analysis, and decision support. This paper will describe a case study from the Coblinine Catchment in Western Australia, where PlanIT is being applied, by Georeality Pty Ltd on behalf of the Upper Coblinine Catchment Association.

The Upper Coblinine Catchment is situated in the South West of Western Australia. The catchment covers an area of 420km². The climate is typically Mediterranean, with cool wet winters, and warm hot dry summers.

The landuse over the catchment is predominantly agricultural with only 8% (~3000ha) of the area having any form of remnant vegetation, or re-vegetation. Agricultural production can also be broken up into two distinct areas. An area above the break of slope produces high yielding grain crops such as wheat, barley, canola and lupins. The area below the break of slope produces grain crops at a lower yield, due to frost and waterlogging. Within this area, approximately 3000ha has been lost to salinity and waterlogging, and a further 6000ha has been recognised as at risk of imminent loss of production [Weir, 2000].

2. PRESENT DAY SURFACE WATER MODELLING

PlanIT incorporates SWAT (Soil and Water Assessment Tool), developed by the US Department of Agriculture for surface water modelling. It is designed to predict the impact of long term land

management practices on water, sediment, and agricultural chemical yields, in large complex watersheds with varying soils, land use, and management conditions [Neitsch, 2001].

2.1. Input Data

SWAT is physically based and requires specific information about weather, soil properties, vegetation, and land management practices occurring in the watershed Neitsch [2001].

An accurate digital elevation model (DEM) with 10m spacing, and 40cm accuracy, was generated from aerial photography. Soil parameters were estimated from published data, as no measurements were available as noted by Armstrong [1991]. A land use map was created from farm information and digitised from catchment orthophotos. SWAT has a database of plants and crops growing in the USA, and required additions for lupins and native vegetation such as Mallee trees. Some plant parameters were unavailable and had to be estimated. Daily and monthly rainfall, temperature, solar radiation, and wind speed were obtained from the Bureau of Meteorology. Geometric information was calculated on the main catchment outlet, reservoirs, and the sub-basins spatial dimensions, average slope lengths and angles. Subbasin land use and soil parameters were added, and the two layers overlaid so areas of unique land use and soils could be extracted to define hydrological response units (HRU's). Data for planting, harvest, irrigation applications, nutrient applications, pesticide applications, and tillage operations were obtained from landholders. The resulting crop rotation was made up of two consecutive years of pasture followed by years of wheat, lupins, and wheat. Finally, information about the engineering works such as grade banks was input.

2.2. Calibration

The model ideally should be calibrated against measured surface runoff, recharge and evapotranspiration values. The nearest continuous flow stream gauge was approximately 70km downstream from the catchment outlet at the Bibikin road bridge (Waters and Rivers Commission), but is probably too far away to be representative. Surface runoff was thus calibrated against the closest non-continuous recording point approximately 20km downstream at the Lake Coyrecup inflow. This has a catchment area of 1756km², with an average annual

flow of 5092x10³ kl and an average annual runoff of 2.9mm. This is similar to values of 1.8mm for the adjacent Blackwood catchment. Recharge was estimated in a previous groundwater model study by Matta [2000] to be on average 8mm per year. Potential evapotranspiration was estimated at approximately 1840mm (Agriculture WA).

2.3. Model Results

The model was run for a time frame of 20 years from 1st of January 1981 to 31st of December 2000. The model was run at daily time steps and all results are annual averages over the 20-year time frame. This time frame was long enough to give a good representation of long term trends in the catchment. The results were output annually and presented in such a way as to highlight areas that contribute to higher than average surface runoff, recharge, and sediment yield. The averaging removed fluctuations caused by crop rotation. Land use was modelled so that all productive land within the catchment had the same crop rotation.

2.3.1. Surface Runoff

Areas of modelled very low runoff coincide with areas of natural vegetation. These results highlight the known efficiency of natural vegetation in reducing surface runoff. Two areas to the east of the catchment with high modelled surface runoff coincide with ridges that divide sub-catchments and have a predominantly clay soil. These areas may require engineering works such as banks, to direct the runoff into key dams before it reaches the valley floor, and increases recharge. Areas of modelled high surface runoff in the main valley floor coincide with areas affected by salinity which are either bare salt pans, or have a poor barley grass cover. These areas require some form of re-vegetation. The highest predicted runoff areas in the west of the catchment may be beyond remediation until ground water level in the area is reduced significantly. These areas require salt tolerant vegetation, or if highly saline, some form of perennial salt bush pasture that can be used for summer stock feed. The highest area in the catchment surprisingly produces very little predicted runoff possibly due to observed deep sandy soils being included in the model.

2.3.2. Recharge

Once again the areas of natural vegetation have the lowest recharge. Higher recharge occurs predominantly below the break of slope, resulting from poorly defined drainage and the flat terrain (<1:800 slope).

2.4. Conclusion

The surface water modelling highlights the need to focus on local issues within individual farms. Prior to modelling it was believed that saline areas along the catchment valley floor had resulted from the rising water table caused by recharge occurring higher up the catchment, in lighter soils, moving laterally downslope. However modelling suggests that higher recharge areas are actually in the valley floors below the break of slope. This, combined with previous groundwater modelling, which found that recharge high in the catchment can take up to a thousand years to reach the valley floor, changes the focus from addressing recharge high in the catchment, to the valley floor. The model also highlights the need for upstream surface runoff, although small, to be contained before it reaches the valley floor. This modelling of surface runoff and recharge identified several approaches to remediation as described below.

3. CATCHMENT/ FARM PLANNING

Having modelled the present day condition of surface water movement, and recharge, in the catchment, catchment members in the landcare group were canvassed in a socioeconomic study [Weir, 2000] to find out their range of remediation options. These alternative land use, engineering, and management options were tested to estimate the most effective method to improve surface water balance.

3.1. Modelled option 1 – Planting lucerne below the break of slope

The present day surface water model highlighted the need for more water efficient farming practices, below the break of slope, to reduce the level of recharge and lower the currently rising water table. Deep-rooted perennial lucerne is capable of reducing recharge and lowering the water table when used within an agricultural rotation. This option was modelled by changing the land use to include a rotation with 4 years of a perennial lucerne pasture followed by wheat, lupins, and wheat.

3.2. Modelled option 2 – Engineering works

One of the main catchment issues is the loss of crop yield, in average to wet years, due to waterlogging of the topsoil. The soils in the region are primarily duplex (sand over clay). Engineering works such as grade and interceptor banks can control waterlogging by intercepting subsurface water and improving drainage as suggested by Keen [1998]. They can also affect recharge, as banks intercept subsurface water, and drain it into defined drainage lines before it recharges groundwater. In this option, banks were added to the crop rotation modelled in option 1 above.

3.3. Modelled option 3 – Revegetation

The presence of natural vegetation can have a large effect on the volume of surface runoff and recharge. Re-vegetation has been a proven method of reducing recharge due to the ability of trees to use large amounts of stored moisture during the summer months. A limiting factor for tree growth is groundwater salinity levels. Above a certain threshold salt tolerant perennial shrubs may be a better option. To model the revegetation option, grade banks, modelled in option 2 above, were vegetated on the down slope side to use seepage that would pass through the bank. Shelterbelts were added parallel to contours, in areas above the break of slope, to act as wind breaks and encourage cultivation along the contour (Figure 1). Alley farming was added below the break of slope, to increase water use efficiency; and all changes, modelled in option 1 and 2 above, were incorporated.

3.4. Modelled option 4 – Key dams and irrigated forage sorghum.

Key dams were modelled along major drainage lines above the break of slope to contain water directed by the banks. These dams were pumped to irrigate sorghum crops, which is both cost effective and prevents the dams remaining at storage capacity, and hence ceasing to be effective storage buffers during some high rainfall years and events.

All previously modelled options remain in the model.

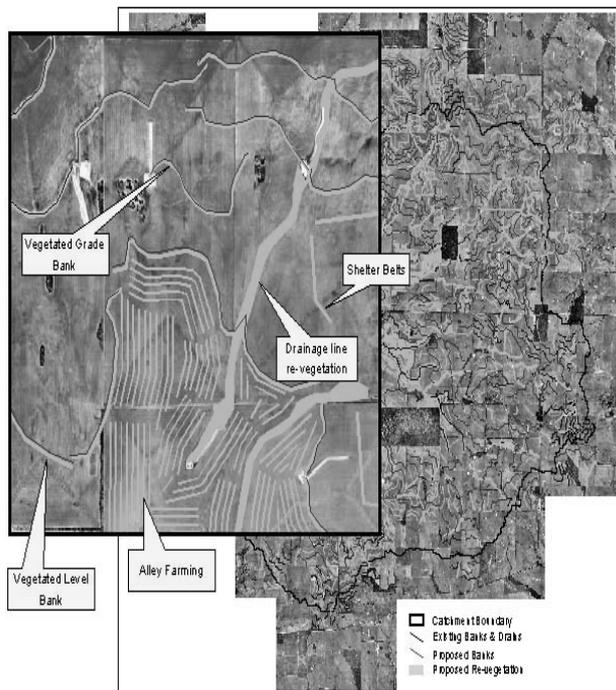


Figure 1. Revegetation above the break of slope

3.5. Results of Farm Plan modelling

By building up and modelling each option sequentially the impact of each can be estimated which may enable a determination of the most effective components of each option to be evaluated. The four options were modelled for the same 20 year time frame as the present day surface water model. The 5 different models were then compared.

3.5.1. Surface runoff

Over the twenty years modelled, growing of lucerne below the break of slope had the biggest impact on surface runoff results, by reducing runoff by 15%. This 15% was achieved by changing the cropping rotations in 22% of the catchment. The introduction of grade banks as expected made very little difference to the surface runoff results. The grade banks increased the length of time runoff would take to reach the valley floor therefore reducing peak flow but did not decrease runoff (Figure 2). The increase in vegetation from 8% to 15% decreased runoff by a further 4%, this low figure highlights that re-vegetation will need to be targeted at the modelled high runoff areas. Key dams and forage sorghum made little difference to surface runoff, but did

reduce the amount of water leaving the catchment. This suggests they would reduce the quantity of water reaching the valley floor, hence reducing flooding and recharge.

Overall the model results show an average of 20% reduction in surface runoff with the implementation of all four options.

3.5.2. Recharge

The first model option had the greatest effect on recharge with a reduction of 14%, particularly below the break of slope. The banks intercept lateral flow through the soil before it becomes recharge, but have a small effect on recharge due to the low gradient and lateral flow rates. Re-vegetation reduced recharge by only a further 3% and hence there may be a need to prioritise the re-vegetation areas to maximise effect. Overall the key dams increased recharge by 0.07mm, possibly due to leakage past the root zone in irrigated areas. This result may be misleading as the model assumes that once water is in a stream channel it doesn't flood. Due to the poorly defined drainage lines below the break of slope, it is not uncommon for this area to flood, causing an increase in recharge. With key dams reducing stream flow, there would also be a decrease in recharge associated with the flooding events.

Overall, all options result in an average 16% decrease in recharge.

3.5.3. Soil Water content

Growing lucerne below the break of slope, for 4 years out of 7, removed excess moisture in the soil, resulting in a 10.1% decrease in average soil water content. It also increased the soil's ability to absorb water during non-lucerne phases of the rotation, hence decreasing waterlogging. Adding banks reduced the soil water content a further 1.3%. A limitation of the modelling is that by calculating annual outputs at 31st December very little indication of the effect banks have on waterlogging during the wetter winter months is given. Re-vegetation further reduced the soil moisture content by 0.4%. The key dams and irrigation reduced this by further 1.4%, for a total reduction of 13.2% for all four options.

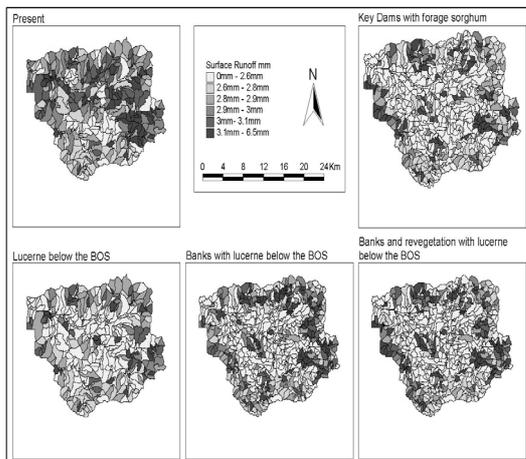


Figure 2. Surface runoff – Options 1-4

4. BENEFIT COST ANALYSIS

A benefit cost analysis was calculated for the whole catchment. The model assessed present and future dollar benefits in relation to the costs involved in investing in the four landcare strategy options above.

It is based on operating incomes for two farms: One "With" and one "Without" any options implemented. The two farms are compared and the difference between them is the benefit (or cost).

It was developed to do three things:

1. To assess profitability for the collective strategy options undertaken on the farm.
2. To obtain economic priorities on the individual options - based on their individual profitability.
3. To obtain values for additional benefits needed to break even on the options - if they are not profitable from productivity benefits alone.

4.1. Input Data

The inputs for the cost benefit analysis were taken from Weir [2000]. This provided information on the total areas cropped to wheat, barley, lupins and canola, crop yields, and stocking rates over the entire catchment. Information on production parameters including average gross margin per ha over the entire catchment for grain, and oilseed, production was taken from Department of Agriculture [2000]. The options to combat catchment degradation were those modelled above. The models were run over 20 years

using a discount rate of 7% with assumed tax deductions of \$50/ha.

4.2. Benefit Cost Results

Perennial pastures gross margin was assumed to be twice the current gross margin for grazing enterprises due to the higher carrying ability of the stock (the model doesn't take into account the loss of production on the land below the break of slope due to frost). Gross margins for Oil Mallees was taken from Holt [1999] and Shea [1999]. The possibility for the sale of carbon credits in the future was not accounted for within this benefit cost analysis. The irrigated forage sorghum can be grazed as well as cut for hay. Forage sorghum has likely yields, if irrigated, of 10 – 15 tonnes to the hectare.

4.2.1. Modelled options

Planting lucerne below the break of slope is the first option. This was established at a cost of \$160 per hectare as shown by Ghauri and Westrup [2000] and Hassall & Assoc Pty Ltd [2001]. Engineering works was the second option. Grade and contour banks would require 333km of earth works estimated at \$4500 per km. Option 3 was revegetation. In which the salt land was re-vegetated with saltbush in identified areas of moderate and severe salt scalding. Remediation costs are 47km of fencing, at \$600/km, and contract seeding costs for direct seeding, including seed, at \$70/ha. Re-vegetation of the creek lines requires 318km of fencing, at \$600/km, with the cost of tree planting including trees at \$270/ha. Oil Mallees are designed as wind breaks throughout the paddocks and planted on the contour. Mallees were also planted on the down hill side of the grade banks to intercept seepage that passes through the banks. The rows are designed on the basis of a commercial mallee farm operation made up of 4 rows (2 hedges) ie 268 trees per hectare at a cost to buy and plant of \$0.6 per tree. In option 4 key dams and irrigated forage sorghum were used. The total costs of creating an irrigated summer pasture of forage sorghum are estimated at: Fencing of 13 paddocks with a total area of 227ha. 21.6km of fencing at \$600/km and purchase of irrigation equipment \$130,000. Pricing for the 13 key dams was estimated at \$20,000 per dam.

5. CONCLUSION

Results suggest that lucerne grown below the break of slope will give the greatest initial benefit in reducing recharge, and surface runoff. The areas below the break of slope are becoming marginal cropping lands, due to recurring frost damage and increasing waterlogging. Growing lucerne would increase the land value due to lucerne's prime grazing quality which requires a trend away from cropping, towards animal husbandry. Lucerne could also be incorporated into cropping rotations above the break of slope, resulting in drying the soil, and decreasing waterlogging in cropping years. Ongoing research in this area will improve establishment systems and other options to allow lucerne, or other deep-rooted perennials, to be successfully incorporated into the broad acre cropping rotations. Incorporating key dams into the catchment will also be necessary to support grazing below the break of slope, as many farmers with land below the break of slope are limited in their grazing potential by a lack of quality stock water. Water from these key dams would be run to tanks or other water storage devices, for grazing animals. These key dams could also support areas of irrigation used for supplementary stock feed. The stream flow results indicate these dams would reduce runoff reaching the valley floor increasing recharge. Overall the modelled options reduced recharge, and surface runoff, significantly, while remaining marginally profitable over the 20 years of the model.

Although the effectiveness of the approach taken cannot be measured till the plans are implemented, land managers in the Coblinine Catchment have already found the results very useful in dividing the management into above and below break of slope strategies. This is flat land and the break was not observed till the high resolution DEM was generated. Based on these results the catchment group will shortly be applying for full implementation funding.

6. REFERENCES

- Armstrong, F.W., An assessment of land degradation and recommendations for its control in part of the Coblinine River drainage system. AGWEST project report. Western Australia, 1991.
- Department of Agriculture – Western Australia. Profitable canola production in the south coastal region, 2000.
- Ghuri, S. and T. Westrup, Saltland pasture makes sense (and dollars!). Department of Agriculture – Western Australia. Memo to the farmer centre for cropping systems, July 2000.
- Hassall & Associates Pty Ltd., A study of the costs of production of lucerne, medic and clover seeds in Australia. A report for the Rural Industries Research and Development Corporation, 2001.
- Holt, C., Eucalyptus oil mallee – Summary Notes. Agriculture Western Australia, 1999.
- Keen, M., Common conservation works used in Western Australia. Resource Management Technical Report 185, Agriculture Western Australia, 1998.
- Matta, J., Groundwater Modelling the Coblinine Catchment, Unpublished report for Coblinine Landcare Group, 2000.
- Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams, Soil and Water Assessment Tool Users Manual, Version 2000, 2001.
- Shea, S., Potential for Carbon Sequestration and product Displacement with Oil Mallees, Agriculture Western Australia Report, 1999.
- Weir, H.T., Socio/Economic Report for Coblinine Catchment Landcare Group, 2000.