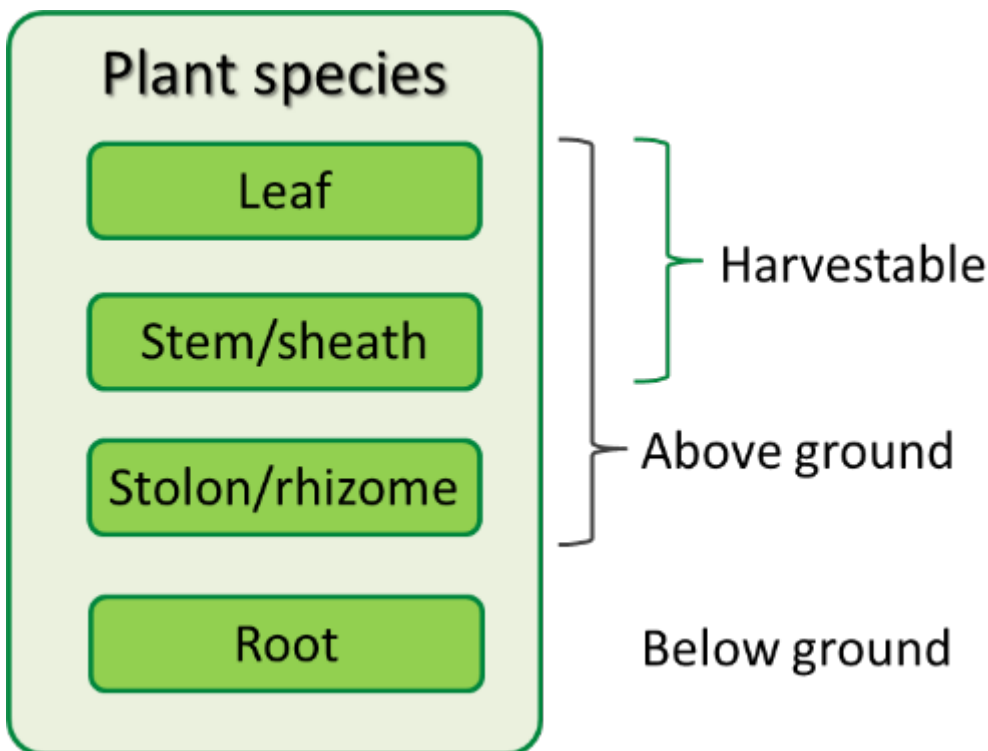


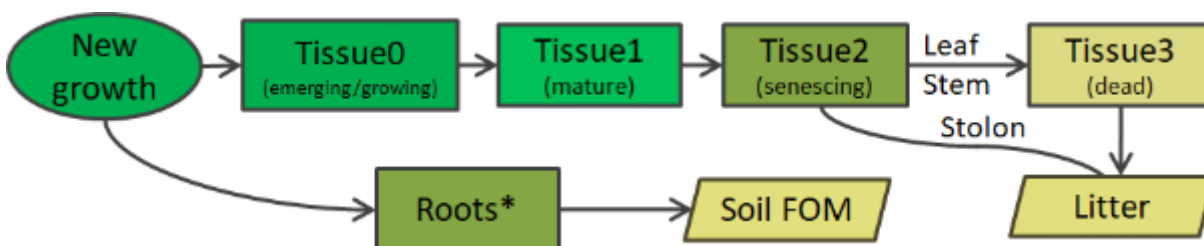


## 1 The APSIM AgPasture Model

AgPasture is a model developed to simulate pasture growth in the APSIM framework. It was initially based on the plant physiological model of [Thornley et al., 1990](#), as were the models SGS/DairyMod/EcoMod, presented by [Johnson et al., 2008](#). Today in AgPasture, the plant processes were adapted from EcoMod but all environmental factors and partition of resources is done by other models in the APSIM framework. The main purpose of AgPasture is to simulate mixed pastures but based on individual calculations for each species of photosynthesis, respiration, dry matter accumulation and partitioning and tissue turnover as presented by [Li et al., 2011](#). It simulates pastures composed by C3 and C4 grasses, legumes and forbs. Now AgPasture has the sward component that is responsible for integrating the outputs obtained for each species and controlling management aspects, such as grazing. The base species in AgPasture is a generic temperate C3 grass parameterised as a generic ryegrass. All simulations are based on an established pasture, so there is no development from seeds. The proportion of species in the sward varies according to environmental effects, water and nutrient extraction ability and effects of harvests (cutting or grazing) on each of the species in the sward. Each species is described as a set of organs (Figure 1) and these organs are described by tissue pools (Figure 2).



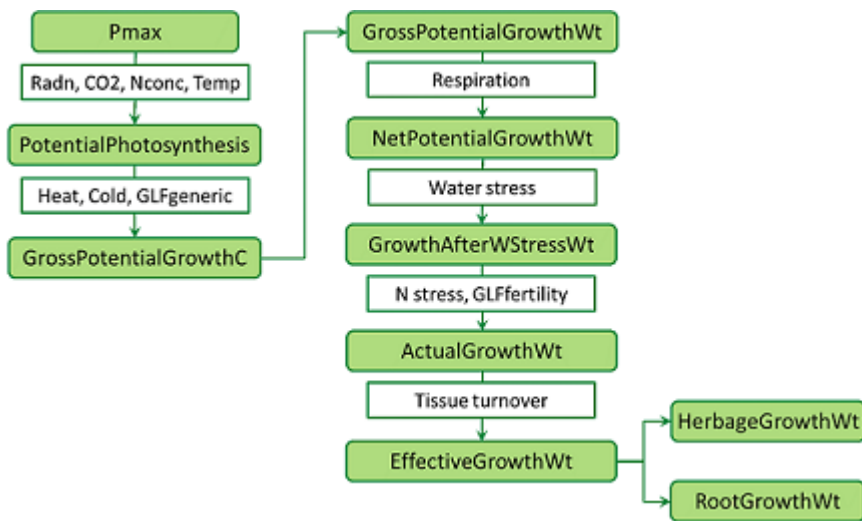
**Figure 1:** Description of plant species in AgPasture with the indication of a general class for plant parts.



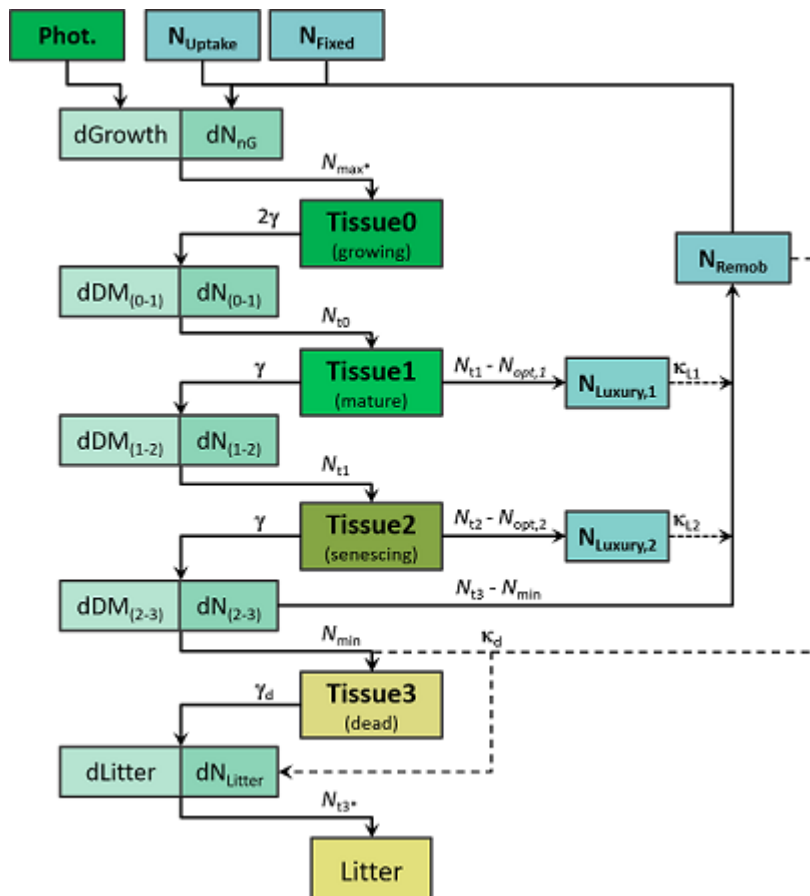
**Figure 2:** Tissue dynamics in AgPasture, from new growth until senescence.

The water demand is calculated by the MicroClimate model (originally micromet; [Snow et al., 2004](#)). Water availability is then calculated according to the root distribution and the KL parameter in the soil. The communication with the soil is mediated by SoilArbitrator, which is also responsible to balance resource competition between plants. Similarly, SoilArbitrator mediates nitrogen availability. AgPasture receives this information and calculates plant potential growth through net photosynthesis and a series of growth limiting factors (GLF), related to water, nitrogen, temperature, fertility (to account for nutrient limitations, other than nitrogen) and a generic factor (to account for the effects of diseases, for

example) are used to reach the actual plant growth. This actual plant growth is what is used for the further processes of tissue turnover and dry matter allocation presented in Figure 3. Dry matter transfer across tissues, how turnover rates act, and nitrogen balance are presented in Figure 4. In general, AgPasture calculates the turnover rates ( $\hat{t}^a$ ) for each tissue pool of all plant organs. The rates are then passed on to each organ and the amounts to be potentially turned over (dDM) are calculated for each tissue pool. For nitrogen, basically AgPasture uses the nitrogen taken up from the soil and fixed by legumes. This nitrogen amount will then be available for new growth. The process of nitrogen uptake aims for the maximum concentration of nitrogen in new growth ( $N_{max}^*$ ). This is not always achieved and the current nitrogen concentration will be added to the pool of tissue 0, which actively contributes with dry matter and nitrogen transfer for older tissues. The same happens for tissues 1 and 2. One of the modifications done in AgPasture for APSIMX is the definition of an adequate nitrogen concentration in these pools. Now tissues have a target concentration of nitrogen and any extra nitrogen is put through the remobilisable nitrogen pool (Vogeler et al., 2016). The rate of nitrogen remobilisation is defined by  $k_L$ , which mainly shows that the priority is the first leaf. When the first leaf becomes deficient, the remobilisation of extra nitrogen aims to fulfill the nitrogen need for this pool. At the same time, a minimum concentration of nitrogen is always transferred to the pool of tissue 3, resulting in a constant nitrogen concentration of this pool. This is then added to the litter pool, where dry matter that comes from the shoot is added to the surface organic matter pool whereas dry matter from roots goes to the soil fresh organic matter pool. The amount of nitrogen remobilisable that was not used is then added to the litter pool.

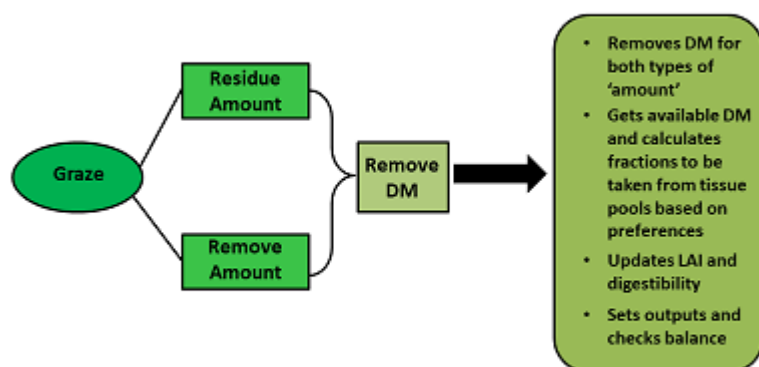


**Figure 3:** Description of growth calculations done by AgPasture, from photosynthesis up to the partitioning of growth between shoot and root.

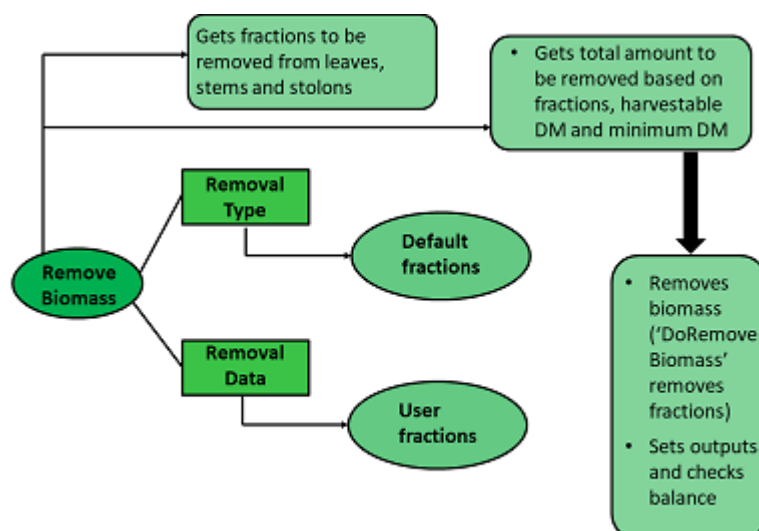


**Figure 4:** Nitrogen balance and dry matter transfer in AgPasture.

AgPasture does not account for phenological development, therefore it does not simulate reproductive growth and seed production. Instead, the model mimics changes in growth rate and dry matter allocation by using a simple function (based on latitude and some species specific parameters) that changes in the shoot:root ratio of plants during this "reproductive period". Another limitation of the model is the lack of carbon remobilisation, which makes it difficult to simulate the proper remobilisation of reserves in the plant. More details are given in the supplementary documentation for AgPasture. Biomass removal can be simulated by the Graze (Figure 5) and RemoveBiomass (Figure 6) methods. The Graze method is a simple way to present the amount of biomass to be removed. It uses a parameter 'Amount', which sets up the amount of dry matter to be removed, and a parameter 'Type', which defines how the value of 'Amount' is interpreted. 'Type' can be set as 'ResidueAmount', where the target amount of dry matter is a value for the residual amount of biomass that will be left after harvest, or it can be set as 'RemoveAMount', where the target amount of dry matter is the value to be removed by the harvest. Both methods are dependent on a minimum above ground green dry matter that is set as a default of 100 kg DM/ha and can never be removed. Then a function 'RemoveDM' is responsible for the dry matter removal and partitions the amount to be removed among organs and pools. This is dependent on default preference values, which are currently set as 1. A series of checks is done to guarantee that mass balance is not affected by the removal of dry matter. The 'RemoveBiomass' method is more elaborate and allows to control the amount of each organ and pool that will be removed. The fractions to be removed can be set through a 'RemovalType' or a 'RemovalData' parameter. The 'RemovalType' is based on default fractions for organs (leaves, stems and stolons) with fractions for live and dead pools of dry matter to be removed and residual dry matter. The 'RemovalData' is optional and allows the fractions to be removed to be set up by the user.



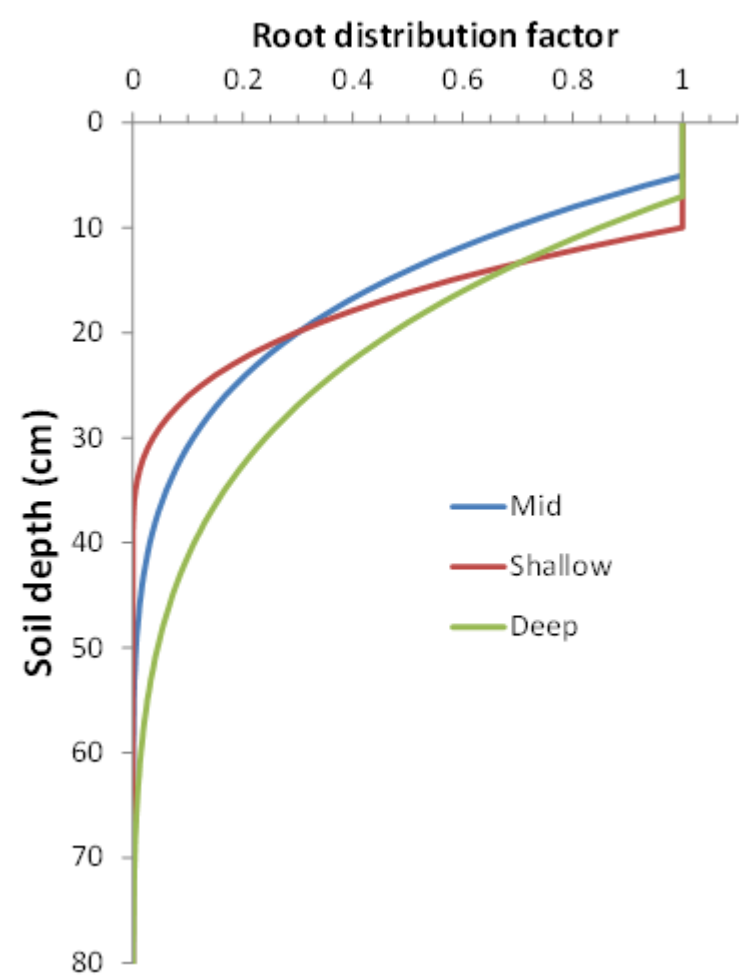
**Figure 5:** Graze method of biomass removal in AgPasture.



**Figure 6:** Description of the RemoveBiomass method in AgPasture

Figure 6. RemoveBiomass method of biomass removal in AgPasture.

Root distribution in AgPasture is give by a simple function, it follows an uniform distribution down to a certain depth, which can be set up by the user. From this depth on, the root system decreases following an exponential decline until no roots are present at the given maximum rooting depth (Figure 7).



**Figure 7:** Example of a shallow, mid and deep distribution of roots in AgPasture.

2 Validation

The validation of biomass production, N status, and relative species composition of AgPasture is done using a series of simulations based on a number of datasets. The base validation uses the 'Radcliffe trials', a series of dataset of yield measured in exclusion cages on grass-clover pastures across New Zealand. The second set comprises of two long term dataset that contain more detailed informatin on management and pasture yield for each harvest, these are a subset of the 'Winchmore' irrigation and fertility trials, with data from ryegrass-clover mixed pastures under rainfed and irrigated conditions, and another set based on production trials in 'Ruakura' [McCall et al., 2003](#). The third set of simulations is based on a fertilisty trial conducted in 'Lincoln' and 'Ruakura' for the Forages for Reducing Nitorgen Leaching programme (FRNL); this encompasses two years of biomass and N uptake measurements under six N fertilisation rates for monocultures of ryegrass and white clover, plus a mix of the two (only in Ruakura).

2.1 NewZealandLongTerm

2.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
Radcliffe	Location (33)

2.1.2 Radcliffe

The dataset used for this simulation is called the 'Radcliffe trials' because it was obtained from experiments done based on the methodology described by [Radcliffe, 1974](#). This comprises a series of measurements on grass-clover pastures to evaluate pasture production across New Zealand. The data was obtained using exclusion cages set up in grazed pastures, with biomass harvested at variable intervals; in few locations plant composition was also determined. The data is presented summarised as the average annual production of dry matter per hectare. This validation set has experiments done in 33 locations, with some comprising two sets due to irrigation, lanscape factors, or different periods of observation. In total, there 37 sets are being used as a validation set for this simulation. Locations such as 'Arrowtown', 'Cromwell',

'Poolburnl', 'Awamoko', 'LowerWaitakiPlains', 'WinchmoreRedcliff' and 'WinchmoreIrrig' are irrigated trials, whereas the remaining locations are rainfed; in none of them N fertiliser was used. Note that in our simulations growth conditions that are not climate or nitrogen driven, are assumed to be non-limiting (i.e. soil fertility, pH, etc. are taken as near optimum and no pests or disease occurred), this is a considerable leap of faith in some locations. Furthermore, the model is not considering variations in cultivars and the presence of weeds and other forages besides ryegrass and clover, plus pasplum for the north-most locations (such variations in species composition are likely to have occurred).

Two more data sets were added to the classic 'Radcliffe trials' with annual average production based on long term data of ryegrass-clover mixtured pasture production trials in 'Ruakura' and two areas in Winchmore ('WinchmoreDland', which is a dryland trial, and 'WinchmoreIrrig', which is an irrigated trial). More information about the 'Ruakura' data set can be found in [McCall et al., 2003](#).

## 2.2 NewZealandDetailed

### 2.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
Winchmore	WaterMgmt (2)
RuakuraNo2	WaterMgmt (1)
FRNLRuakuraMixedSward	NRate (6)

#### 2.2.2 FRNLWClover

##### 2.2.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
FRNLLincolnWClover	NRate (6)
FRNLRuakuraWClover	NRate (6)

#### 2.2.3 FRNLRyegrass

##### 2.2.3.1 List of experiments

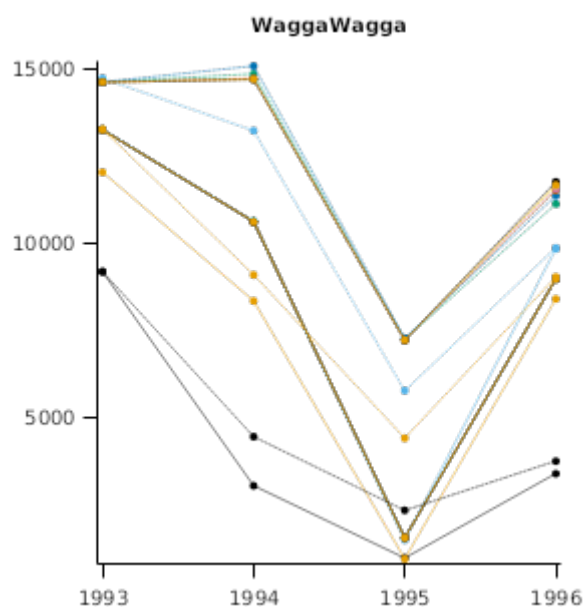
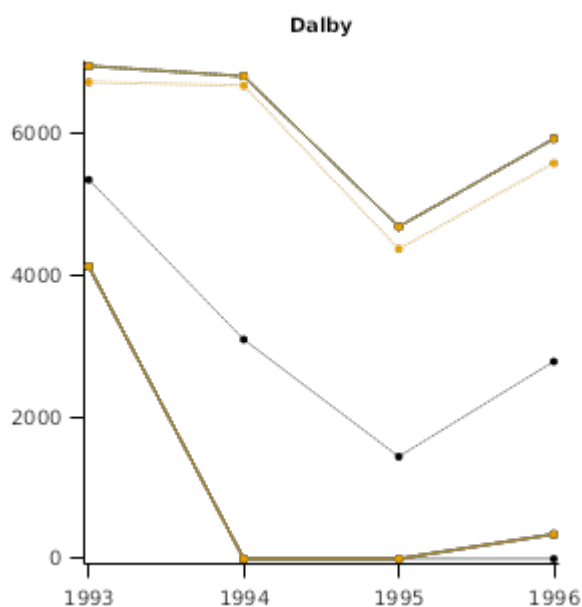
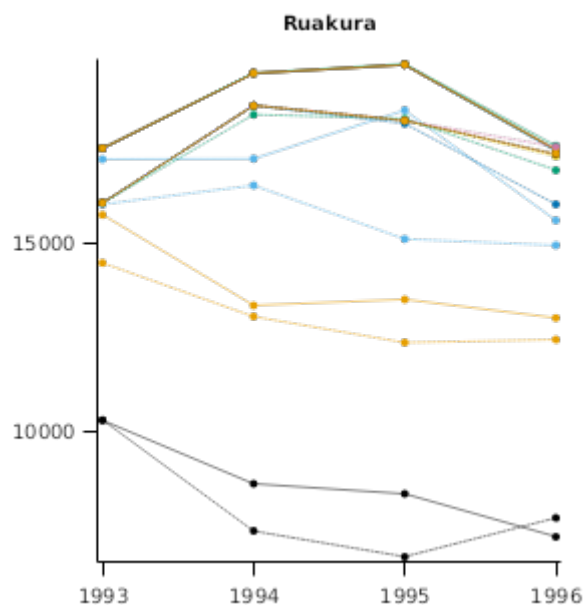
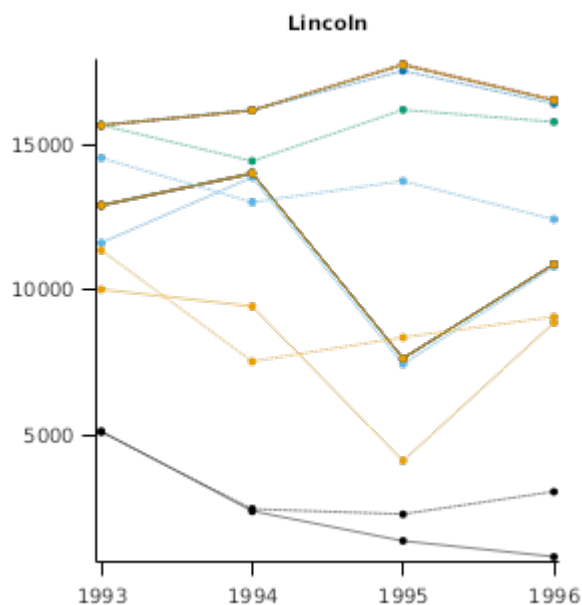
Experiment Name	Design (Number of Treatments)
FRNLLincolnRyegrass	NRate (6)
FRNLRuakuraRyegrass	NRate (6)

## 3 Sensibility

### 3.1 List of experiments

Experiment Name	Design (Number of Treatments)
Sensibility	Location x Nitrogen x Water (80)

### 3.2 Sensibility



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