15. RECOMMENDATIONS.

The following is a list of recommendations relating to the use of P in agriculture that are applicable to both the use of fertilisers and organic manures. Of the major plant nutrients, the World's resources of P are least and on a global scale P should, therefore, be used as efficiently as possible to maintain and increase agricultural productivity where appropriate. In England and Wales there is evidence that on "The National Farm", the P balance (P applied *minus* P removed in the harvested crop) is negative for the most important arable crops where animal manures are not applied. As only 16% of the total tillage area gets organic manure annually this implies that a negative P balance exists for most soils growing arable crops. This cannot continue indefinitely without risk to the fertility of these soils with respect to P. Soils containing insufficient P not only produce less yield but other inputs, notably N, are used less efficiently. Highlighting the risk associated with incidental P transfers and targeting short-term decision-making is perhaps the most immediately viable method for mitigating P transport from soil to water. The recommendations that follow should be considered as approaches to limit any transport of P from agriculturally managed soils to water.

- Identify the critical level of plant-available P for each soil and farming system. In the absence of field specific data, current advice in RB 209 to increase the P in the topsoil to P Index 2 for intensive grassland and most arable crops and Index 3 for potatoes and vegetables is an acceptable starting point. Deep, well-structured soils with good seedbeds will have lower critical values than shallow or stony soils because the former have more fine soil particles on which plant-available P is held and roots are better able to produce a good root system in well structured soils.
- Maintain soils at the critical level of plant-available P appropriate to the soil and farming system by replacing the P removed in the harvested crop, maintenance applications as indicated in RB 209. The soil should be sampled every 4/5 years to check that this approach to P fertilising is maintaining the critical soil P value. Current evidence suggests that the critical value is independent of the yield but with larger yields the P offtake, and thus the maintenance application will be larger. Average values for P offtakes per tonne of produce removed from the field are in RB 209 (MAFF, 2000).

- Always take soil samples at the same time of year, to the same depth and take not less than 16 cores to provide a bulk sample. Unless fields are known to be very uniform it is preferable to take separate samples from restricted areas representative of known differences in soil conditions. In normal farming systems, soil P values rarely change rapidly or erratically, if large changes are reported they should be queried, and if necessary fresh samples taken for analysis. Large changes in soil P values do not occur quickly with either positive or negative P balances. When P balances are positive, much of the excess P moves quickly to absorbed forms that are not measured by routine methods of soil analysis. When P balances are negative, P from the less readily available pool replenishes that in the readily available pool (see Figure 3).
- Do not allow plant-available soil P values to increase much above the critical value. When soils with P values much above the critical value are transported to a surface water body there is an increased risk of adverse effects from eutrophication. In grassland farming systems where the soil is rarely ploughed, the surface few centimetres of soil become greatly enriched with P, especially where slurry is added frequently. In such situations and in relation to assessing environmental risk, it may perhaps be necessary to consider the depth from which soil samples are taken.
- When assessing the field specific requirement for P fertiliser, farmers should consider not only the existing soil P level but calculate possible contributions from other sources of P, like organic manures and sewage sludge that are available and could be applied. Final adjustments to the amount of P fertiliser to apply are based on the actual application from other P sources.
- Improve the recycling of P within the soil – plant – animal system because P is a finite resource. There are major opportunities for recycling P in animal husbandry systems. RB 209 gives data on the "immediate" availability of P in different manures. But for fields at the critical level of P it is more important to check that, as with fertiliser P, any organic P input is maintaining the critical soil P level.
- Use all organic manures in accordance with Codes of Good Agricultural Practice, especially in relation to the time of application and amount applied. Do not apply slurry when soils are saturated with water, *i.e.* are at field capacity. Where slurry is to be applied maintain a good soil structure, especially at the surface, to allow rapid penetration of the slurry. On arable land tine cultivate the soil prior to slurry application or plough it in soon after application. Do not apply slurry when it is raining or rain is forecast. Avoid an unnecessary build of P in soil by applying organic manures on a rotational basis.
- Identify and quantify P transport processes and the factors that control them in both spatial and hydrological terms within a catchment to decide appropriate control methods to minimise P transfers. Soils with different properties can occur within small areas even within a field, let alone a whole catchment, making it difficult to predict water discharge and P load. It is essential to recognise that the transport of P will not be uniform over a whole catchment and that the most vulnerable areas must be identified and remedial measures concentrated in those areas.
- Do not apply P, either as fertilisers and manures, to cracking soils while the fissures remain open.
- Do not apply P, either as fertilisers or manures, to soils that are dry and hard or saturated with water when there is risk of heavy rainfall, especially in undulating terrain.

- Maintain a surface cover of vegetation for as much of the year as possible. The movement of soil by water is related to both the intensity of rainfall and the number of intense rainfall events, especially on bare ground.
- Maintain the structural stability of a soil by timely cultivations and by minimising traffic over the soil surface and poaching by livestock when the soil is wet. Structural stability is related to soil texture and to the calcium carbonate and organic matter content. Experimentally restricting the flow of drainage from under-drained soils has lessened the P concentration in the drain flow without decreasing yields in field experiments. Minimising drain flow from soils in areas with significant eutrophication problems might be considered. This could perhaps be done by mole draining less frequently. But before such an approach could be recommended much further work needs to be done to identify the window of opportunity for soil cultivations and drilling.
- Minimising soil erosion by water and wind is an essential step to minimising the transport of P to water. Minimising tillage operations, improving the timeliness of cultivations, maintaining soil structural stability and retaining soil surface cover by leaving crop residues on the surface are potentially useful actions to minimise the transport of P from soil. Introducing riparian zones is another approach. However, cultivations across slope rather than up and down slope to minimise soil erosion can have safety implications for those operating machinery and un-decomposed crop residues on the soil surface can interfere with subsequent drilling.
- A better understanding of the relation between forage maize yield and its requirement for P is essential. The land on which maize is grown usually receives large applications of slurry and additional amounts of P fertiliser. The rationalisation for this pattern of manuring must be understood because experimental evidence suggests that large amounts of P can be lost from soils treated in this way.
- On non-calcareous soils (*i.e.* soils with a pH less than 7) maintain the pH of arable soils at pH 6.5 and grassland soils at pH 6.0 to help maintain soil structural stability and yield.
- Consider the advantages/disadvantages of placing P fertilisers below the soil surface, especially on light textured arable soils. This has the possibility of improving P fertiliser use efficiency but it is not yet known whether placing P fertiliser to the side and below the crop row would allow soil to be maintained at a lower critical value than presently recommended. It would still be essential to replace the amount of P removed in the harvested crop. There could be disadvantages on heavier textured soils where, as the soil dried, invariably cracks would open up along the line that the placement tines had travelled. These cracks would allow the ingress of eroded soil and organic manures and could increase their transport to depth.
- The application of both slurry and P fertilisers should aim to maintain the appropriate level of plant-available P for the farming system and soil type. Fertilisers with their larger concentration of P and physical properties can be stored and then applied at more appropriate times than slurry.