The influence of Natural Sequence Farming stream rehabilitation on upper catchment floodplain soil properties, Hunter Valley, NSW, Australia

Nathan Weber[A] and John Field[A]

[A]Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200, Email nathan.weber@anu.edu.au

Abstract
Upper catchment floodplain soils under long-term (30 years) Natural Sequence Farming (NSF) management are compared with soils managed under conventional farming to determine whether any significant changes occur in soil physical, chemical and biological properties. The results show significant changes in total and available phosphorus concentrations, effective cation exchange capacity and soil macro-biota abundance and diversity. The electrical conductivity results showed a relatively neutral response while the total nitrogen, organic carbon and bulk density values suggest a negative response to NSF. However the higher grazing pressure and hay cutting occurring on the NSF sites confounds the soil organic carbon and bulk density results. This suggests that NSF has potential for soil improvement in an agricultural floodplain setting, however suitable pasture management systems must also be applied otherwise they appear to be an over-riding management factor for some soil properties.

Key Words
Soil fertility, stream-floodplain connectivity, soil fertility.

Introduction
Natural Sequence Farming (NSF) seeks to re-instate stream-floodplain connectivity in incised stream channels through the placement of 'leaky weir' structures within the incised channel (CSIRO 2002). This is in an attempt to slow stream velocity and increase stream base level and stage height to enable lateral transfers of water into the floodplain sediments (Keene *et al.* 2007). The ultimate aim is to restore the alluvial aquifer watertable to a height where it interacts with the soil profile. This interaction is thought to have occurred in the chain of ponds and swampy meadow floodplain morphologies that typified upper catchments prior to land degradation and resultant stream channel incision (Eyles 1977; Prosser 1991). This study investigated the effects of long-term (approximately 30 years since initiation) NSF management on upper catchment floodplain soils located on a grazing property along the Bylong Creek in the upper Hunter Valley, NSW. The NSF managed soils were compared with conventionally managed soils to determine whether any significant changes occur in soil physical, chemical and biological properties in relation to agricultural productivity.

Methods
The sample sites selected included three sites on both NSF managed paddocks and paddocks situated upstream and adjacent to the NSF managed paddocks which were selected as the conventional farming control (Non-NSF). The sample sites were paired based on the floodplain position, surface soil type, and adjacent channel morphology on the NSF and Non-NSF managed land. An attempt was made to position sites just behind the levee and use average floodplain soils (essentially loams and neither levee nor true backplain nor palaeo versions). These paired sites were:
- downstream of NSF structure/downstream of narrow incision;
- NSF structure/narrow channel incision; and
- NSF created channel pool/incised channel scour pool (Figure 1).

In order to pair the sites based on these hydrogeomorphic features concessions were made regarding the land use. The NSF sites were subjected to a relatively higher grazing pressure and to some hay cutting compared to the Non-NSF sites which formed part of a recently set up stock-excluded riparian reserve (approx. 3 years of exclusion). Thus measured changes in soil properties on the NSF sites should be emphasised as these are despite the differential in land use. The paired sites were aggregated for each treatment (NSF and Non-NSF) to compare any effects of management type across all sites. Thirty-one soil samples were collected per site along bisecting transects during April 2008 (Figure 2). Subsequent laboratory analyses carried out according to standard analytical methods (Table 1). Statistical significance was determined by t-tests.

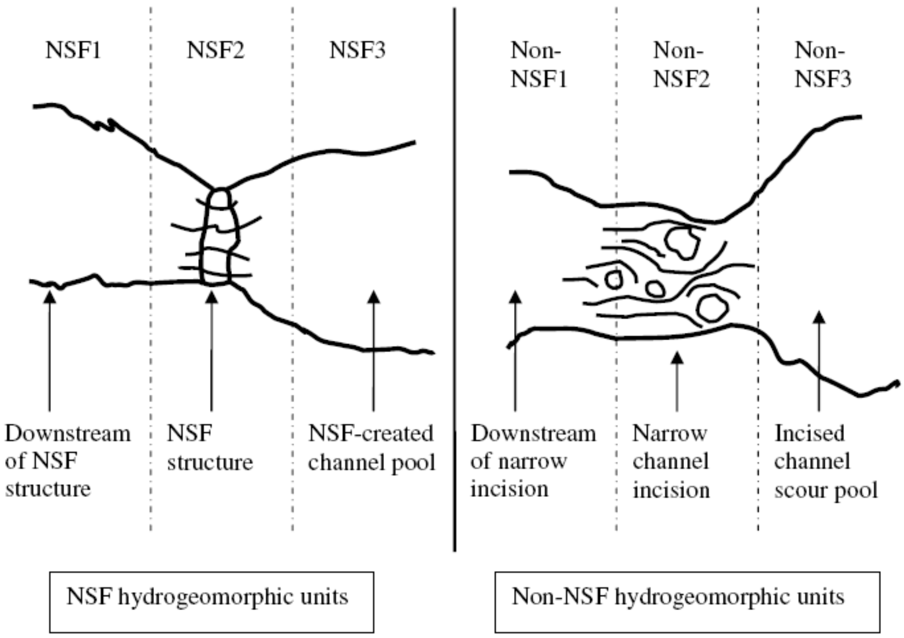

Figure 9. Schematic layout of sample site pairing to effectively compare hydrogeomorphic influences on the floodplain soil (water flow from right to left).

Table 10. Soil property and the laboratory analyses conducted.

Soil property	Laboratory analysis
Total P (ppm)	Acid digestion and Technicon Autoanalyser
Available P (cmol/kg)	Water extraction and ICPAES
ECEC (cmol/kg)	Water extraction and ICPAES
Macro-biota abundance (indiv/core)	Temperature gradient extraction and microscope counts
Macro-biota diversity (func. grps/core)	Temperature gradient extraction and microscope counts
ECe (dS/m)	1:5 soil:water suspension and conductivity probe
Total N (ppm)	Acid digestion and Technicon Autoanalyser
Bulk density (g/cm^3)	Oven dried weight of uniform soil cores
SOC (%)	Walkley & Black (1934)

Results

From the comparison of the paired sites it was found that significant differences (*P<0.05*) do exist between the soils sampled under the different management regimes and this suggests that NSF management practices influence at least some of these differences. The effects of current land use (i.e., hay cutting and grazing pressure differences) also seem to counteract NSF treatment effects. The soil properties found to support NSF practices were (Table 2): total and available soil phosphorus, effective cation exchange capacity (ECEC), and soil macro-biota abundance (individuals/core) and diversity (functional groups/core). However, other analyses show either a relatively neutral (ECe) or negative (total nitrogen) effect on soil properties and potential productivity. Other soil analyses including bulk density and soil organic carbon (SOC) percentages suggest that the current grazing pressure (i.e., around 3 years) on the land is an over-riding control that obscures any effects that NSF may have on these properties.

Table 11. The measured values for a range of soil properties on NSF and Non-NSF sites. Standard error is in parentheses and P<0.05 for all values.

Soil property	NSF managed sites	Non-NSF managed sites
Total P (ppm)	938.59 (24.25)	827.19 (19.34)
Available P (cmol/kg)	0.12 (0.01)	0.05 (0.01)
ECEC (cmol/kg)	34.54 (2.30)	29.58 (2.13)
Macro-biota abundance (indv/core)	9.81 (1.21)	6.76 (1.07)
Macro-biota diversity (func. grps/core)	2.67 (0.34)	1.67 (0.26)
ECe (dS/m)	1.32 (0.08)	1.03 (0.07)
Total N (ppm)	3547.13 (135.56)	4560.71 (155.47)
Bulk density (g/cm^3)	1.02 (0.03)	0.85 (0.06)
SOC (%)	4.99 (0.16)	6.08 (0.20)

Discussion

The influence of NSF management on soil properties is relatively unknown, thus the results of this study cannot be assessed in the context of similar studies, as none exist. Therefore, the results are assessed in the context of the possible explanations for the changes in soil properties as identified in the literature. The NSF predictions of an increased height in the alluvial aquifer watertable and consequent increases in the soil moisture content are used as the basis for this assessment. The inferred soil processes occurring as a result of NSF management include:

- Increased soil moisture as a result of higher soil watertables and capillary rise and consequent increased biomass growth, nutrient cycling and organic turnover (Guobin and Kemp, 1992; Jobbagy and Jackson 2001);
- changes in redox potentials in the bulk soil and microsites altering biogeochemical cycling and availability (increased soil phosphorus and decreased nitrogen) (Baldwin and Mitchell, 2000; Sleutel *et al.* 2008); and
- increased soil moisture levels and persistence (increased soil macro-biota abundance and diversity) (Spain and Hutson, 1983; King and Hutchinson, 2007).

It must be noted that the alluvial sediments of floodplains in the upper Hunter Valley are composed of sandy textures (Kovac and Lawrie, 1991), thus allowing for potentially high transmissivity and infiltration of rainfall and stream water. Therefore it is debateable whether NSF techniques have the same potential for soil improvement in clay dominated floodplain systems where movement of water into and through the alluvial aquifer is more restricted due to the confining pore space.

This study highlighted the changes in soil properties a higher watertable can have in an upper catchment floodplain. The follow up study to these results is investigating remnant chain of ponds to compare with downstream incised floodplain soils to characterise any loss of soil quality following channel incision. This characterisation will be used as a basis for assessing the ability of NSF techniques to improve soil conditions from those of incised floodplains to high alluvial watertable floodplains, as is found in chain of ponds systems.

Conclusion

Based on the potential increases in the watertable and soil moisture as predicted by NSF concepts and the broader literature, NSF management appears to have major influences on the soil chemical and biological properties. Furthermore, the only definitive result that shows NSF is having adverse effects on floodplains soils is the reduction in total nitrogen. Despite the fact that the grazing pressure and hay cutting appears to confound the organic carbon and bulk density results, the remaining results are still positive. Finally, this study highlighted several areas where current research seeks to improve the understanding and quantification of the potential and actual effects NSF management has on floodplain soils. In particular, quantifying any changes resulting from stream channel incision

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