

Effects of subsurface treatment of acid sulfate soils on water quality

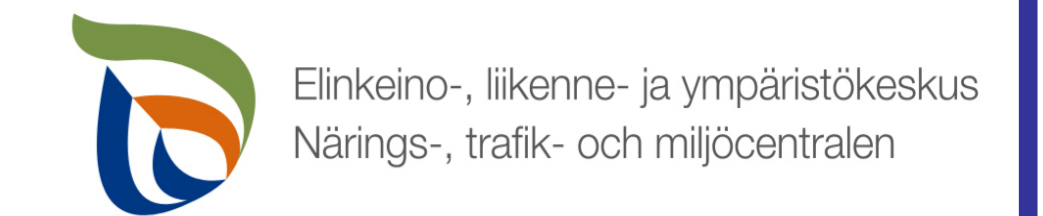
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Background

Upon drainage sulfide-bearing sediments oxidize and develop into acid sulfate (a.s.) soils (pH < 4) and large quantities of acidity and soluble toxic metals are released along the drainage channels to recipient waters with detrimental environmental consequences. Provided that oxygen is initially available, the acid and metal release from a.s. soils is catalyzed and largely controlled by the activity of acidophilic microorganisms (Wu et al. 2013). As the farmlands situated on the potentially a.s. soils are some of the most productive ones, there is an urgent need to find methods and agricultural practices by which these lands may be used in an environmentally sustainable way. Minimizing sulfide oxidation by preventing groundwater lowering, i.e. aeration of the sulfidic sediments, during summer droughts is the most obvious environmental measure that should be aimed for on farmland a.s. soils. Due to a well developed soil structure and strong evapotranspiration in the summer, this is challenging.

Methodology

Controlled subsurface drainage has been used on some sites in Finland in order to counteract the groundwater recession. In addition, at the PRECIKEM experimental field in western Finland (Fig. 1), controlled drainage with plastic sheets was installed for preventing by-pass flow to the main drains (Fig. 2). Moreover, suspensions of ultra-fine grained CaCO_3 and Ca(OH)_2 were injected through subsurface drain pipes into the soil of four identical 1 hectare subfields (Fig. 3) in 2012 and 2013. The aims of the treatments were to (1) neutralize the acidity and immobilize metals in the vicinity of the hydrologically active soil macropores and (2) hamper the microbially mediated sulfide oxidation. In this study we present the preliminary results of the large-scale subsurface treatments on the drainage effluent water quality.

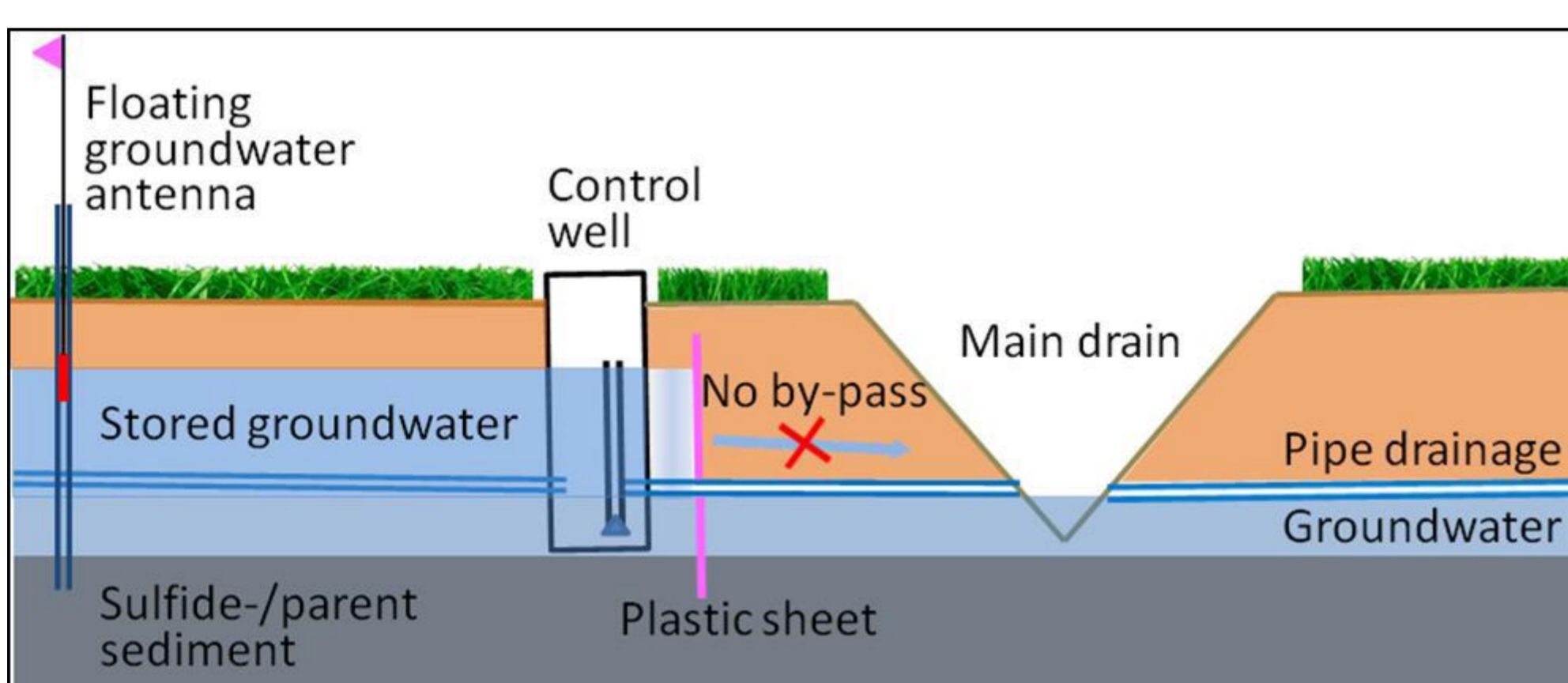


Figure 2. Controlled drainage with plastic sheet for by-pass flow prevention. The plastic sheet has to reach the sulfide/parent sediment (to a depth of c. 1.8 m) for preventing acidic water to escape to the main drain.



Figure 3. On the left: Preparing of the suspension in a mixing container. On the right: Injection of the suspension via the control well into the drain pipes. Each treatment were performed on two subfields during summer droughts. Treatments in 2012: c. 700 kg CaCO_3 and c. 150 kg of Ca(OH)_2 mixed with 100 m³ water and in 2013: c. 370 kg of CaCO_3 and c. 360 of Ca(OH)_2 mixed with 120 m³ water.

Results/Summary

In the drainage waters of reference subfields (treated with water only) the pH was around 4 and the acidity up to 5 mmol/L (Fig. 4a), during flow events in autumn and spring. Concentrations of metals were extremely high (Fig. 5). In subfields treated with CaCO_3 the corresponding pH the subsequent autumn and spring increased, and the acidity was halved (Fig. 4c and d). For the metals, the most remarkable change was found for the acid-sensitive Al that decreased with more than 95 % (Fig. 5). No significant decrease in the concentration of sulfate were observed, indicating that the short term reductions in metal concentrations are not related to less oxidation but to the pH increase. Investigation of the drain pipes with a fiberscope revealed that while some of the CaCO_3 was stored in the uppermost section of the drainpipes, most of the suspension had been transported and retained in the soil pores (Fig. 6), probably relatively close to the subsurface drain pipes. With the Ca(OH)_2 treatment, the effects on the water quality were small after the modest treatment in 2012 but significant after the higher dose in 2013 (Fig. 4b). In conclusion, the short term effects of the subsurface treatments were remarkably good, particularly with CaCO_3 , but further monitoring of the water quality is needed in order to determine long term effects.



Figure 6. Suspension retained in the soil pores.

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Figure 1. The PRECIKEM experimental field in western Finland.

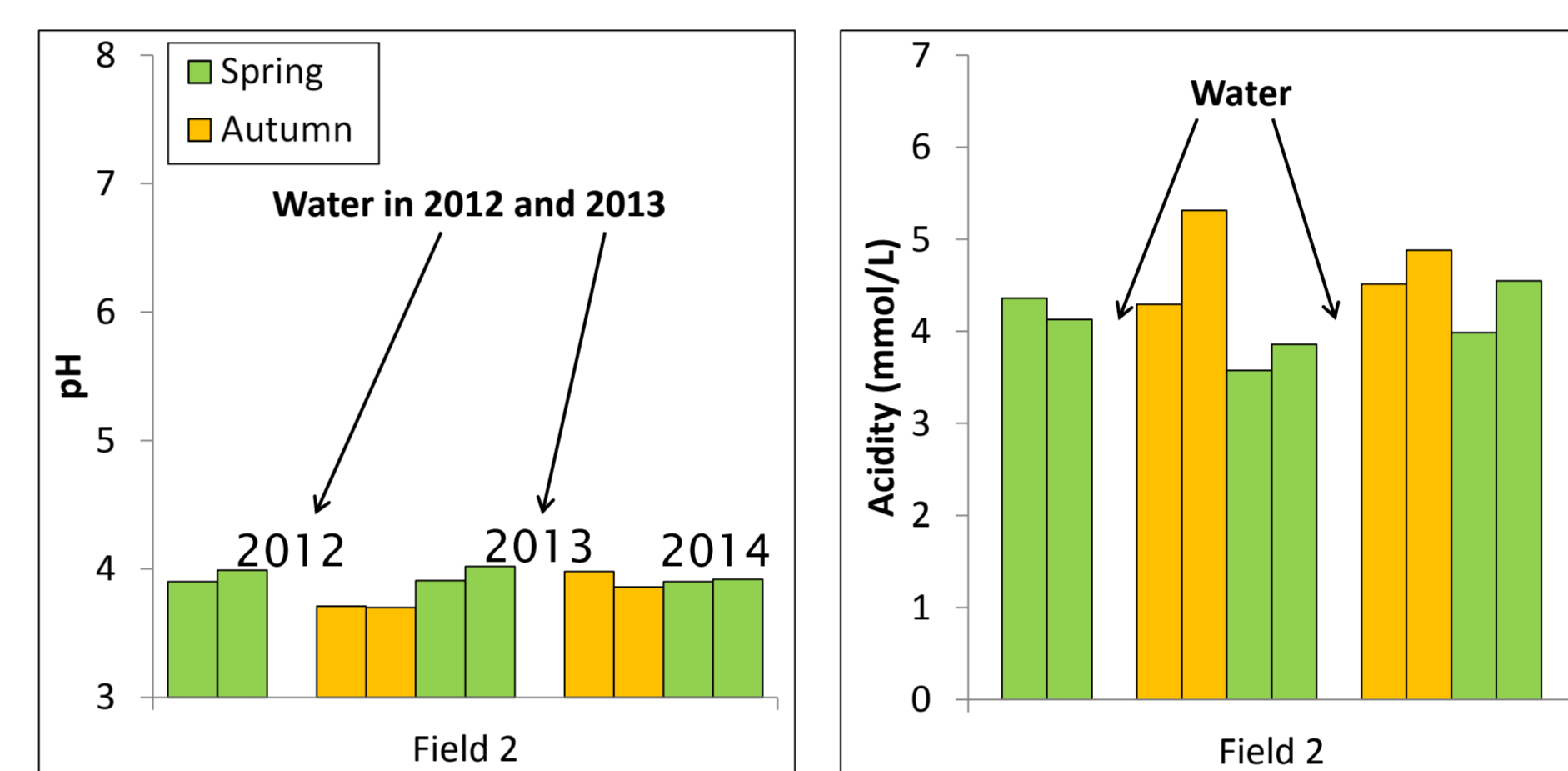


Figure 4 a. Reference field (water). The pH was low (c. 4) and the acidity high (between 4 and 5 mmol/L).

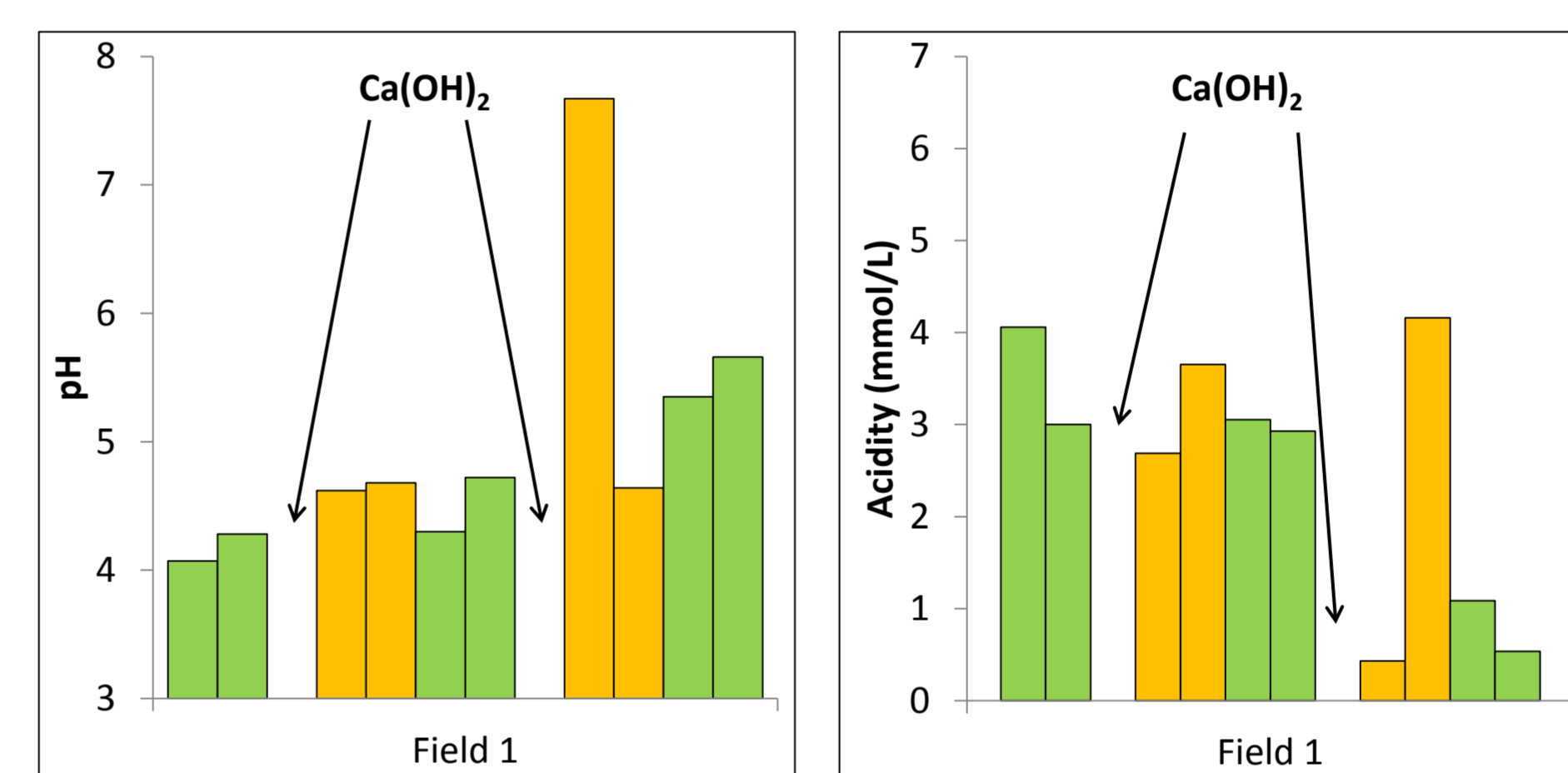


Figure 4 b. Effects of a small (in 2012) and a large (in 2013) dose of Ca(OH)_2 . There was no significant effect of a small dose. A high dose, however, increased pH and decreased acidity significantly.

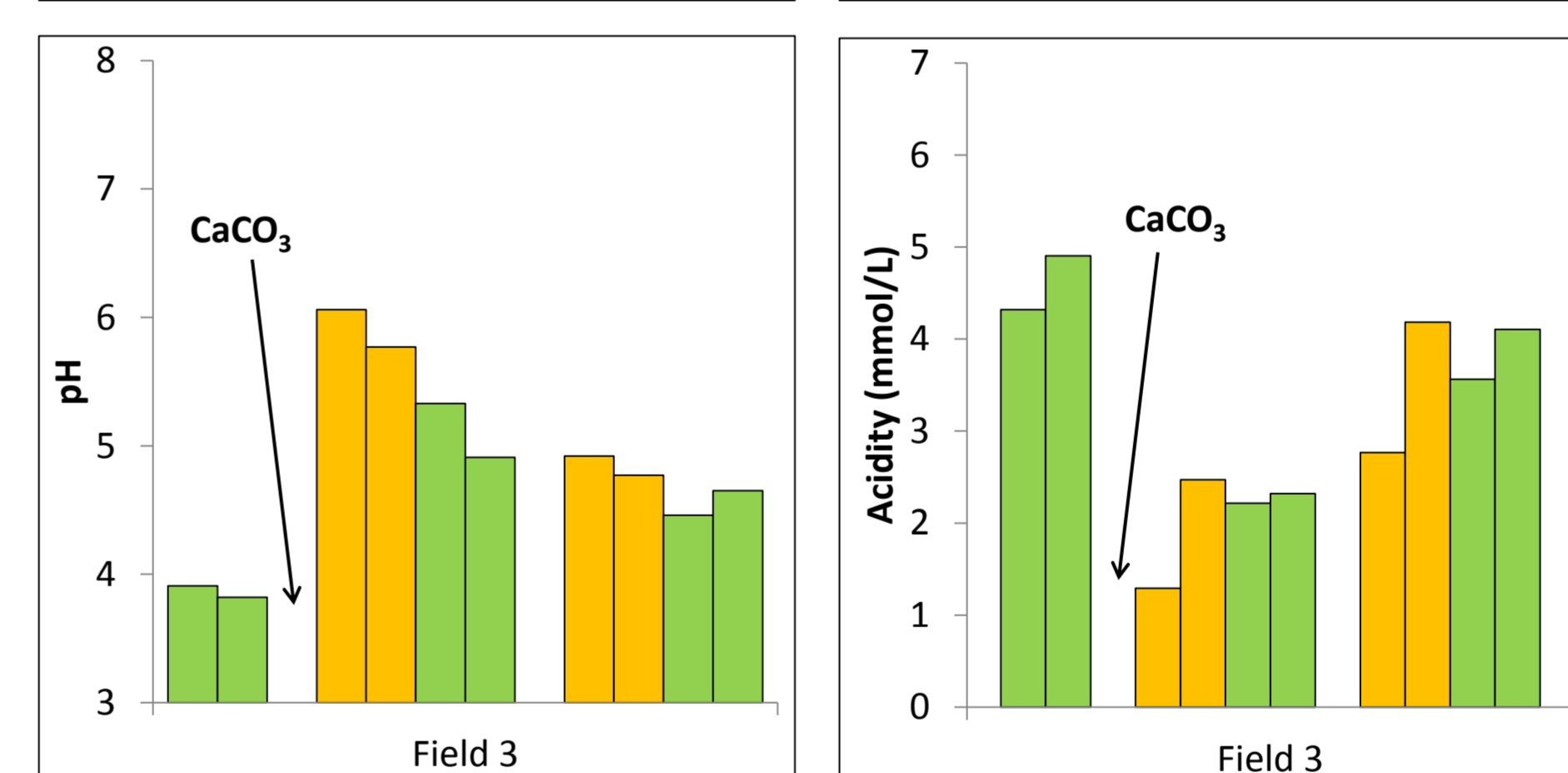


Figure 4 c. Effects of a large dose of CaCO_3 . After the injection the water quality improved significantly and still a year after the treatment the water quality was fairly good.

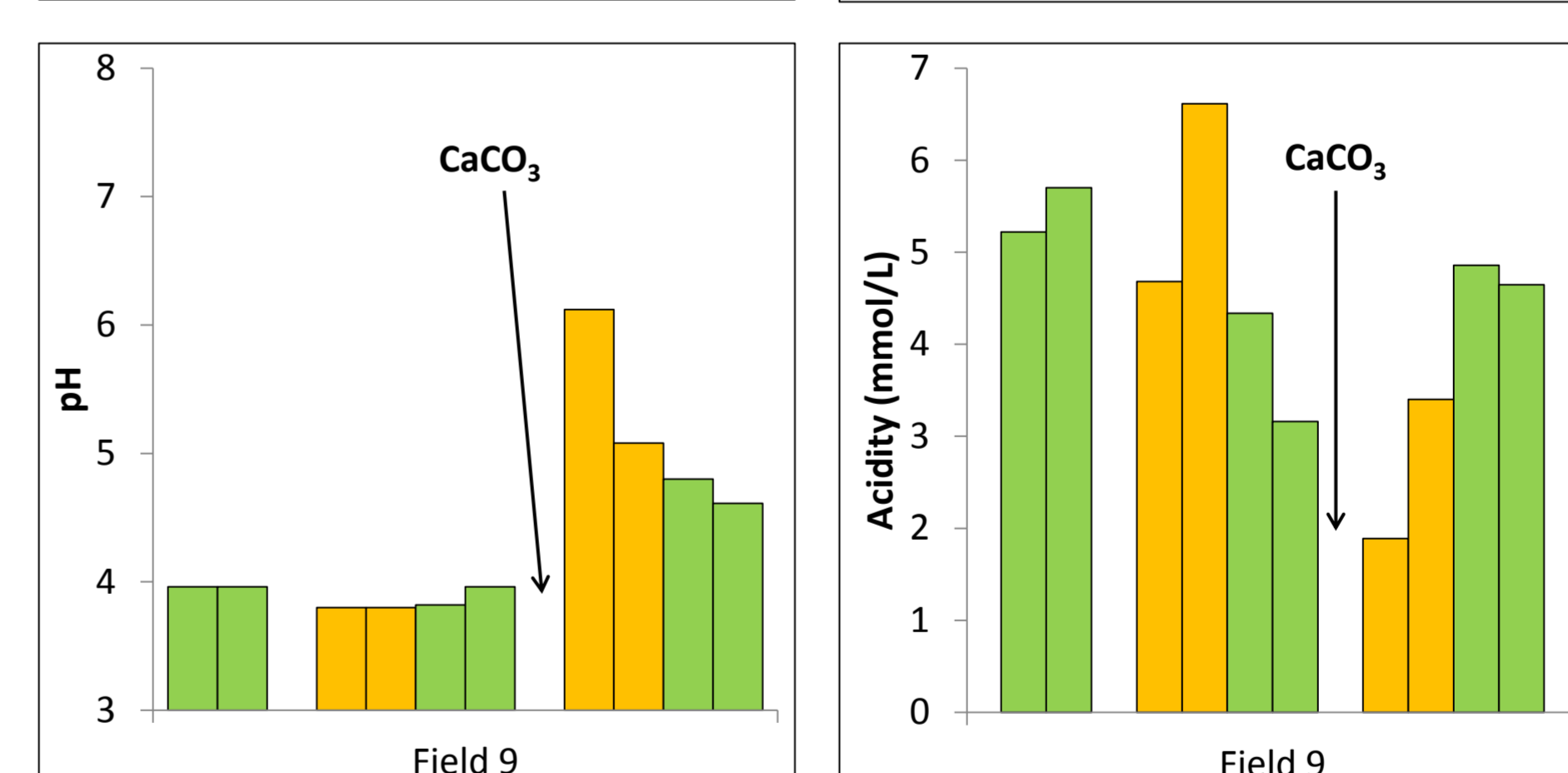


Figure 4 d. Effects of a small dose of CaCO_3 . After the injection the water quality improved significantly.

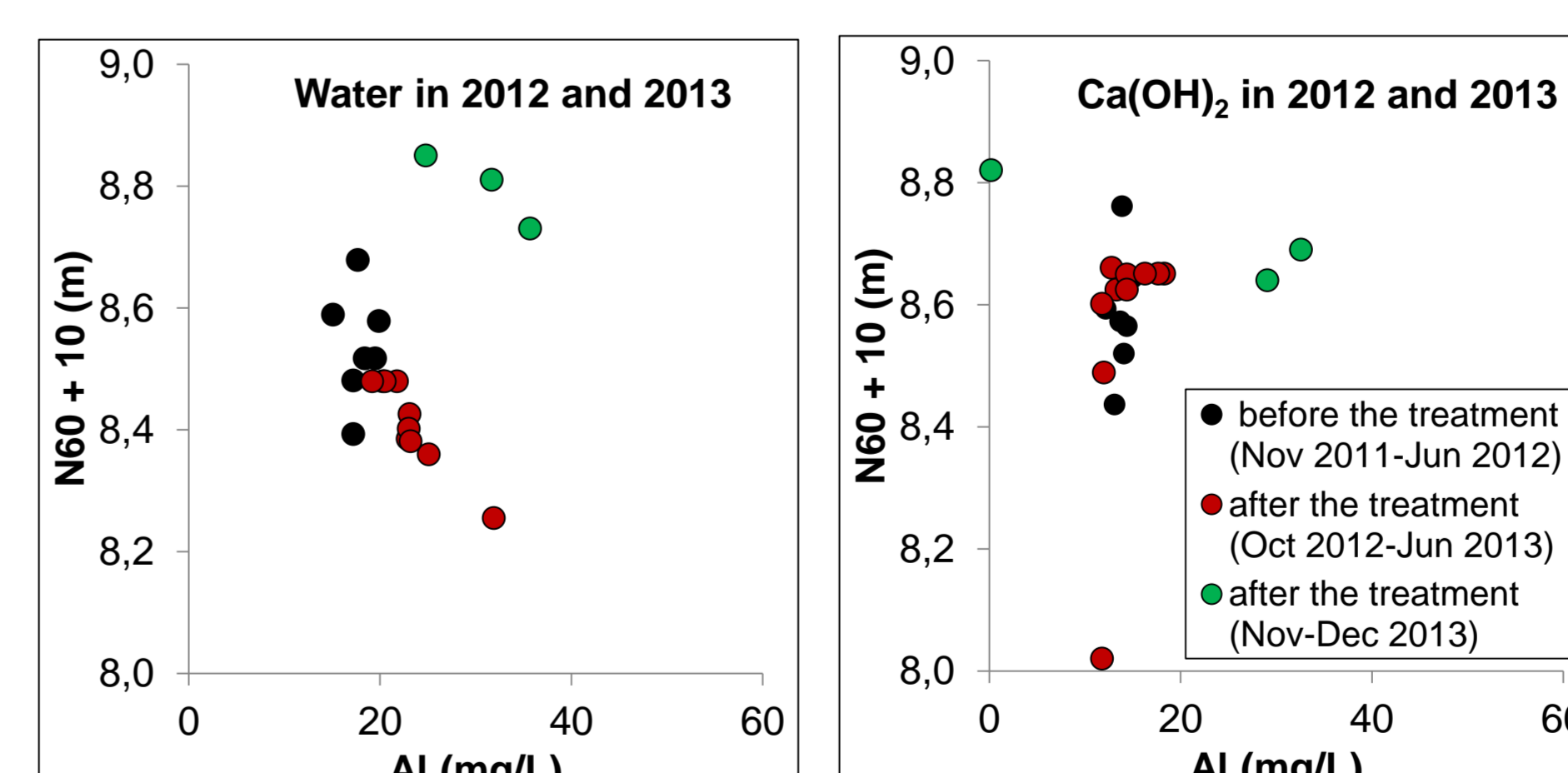
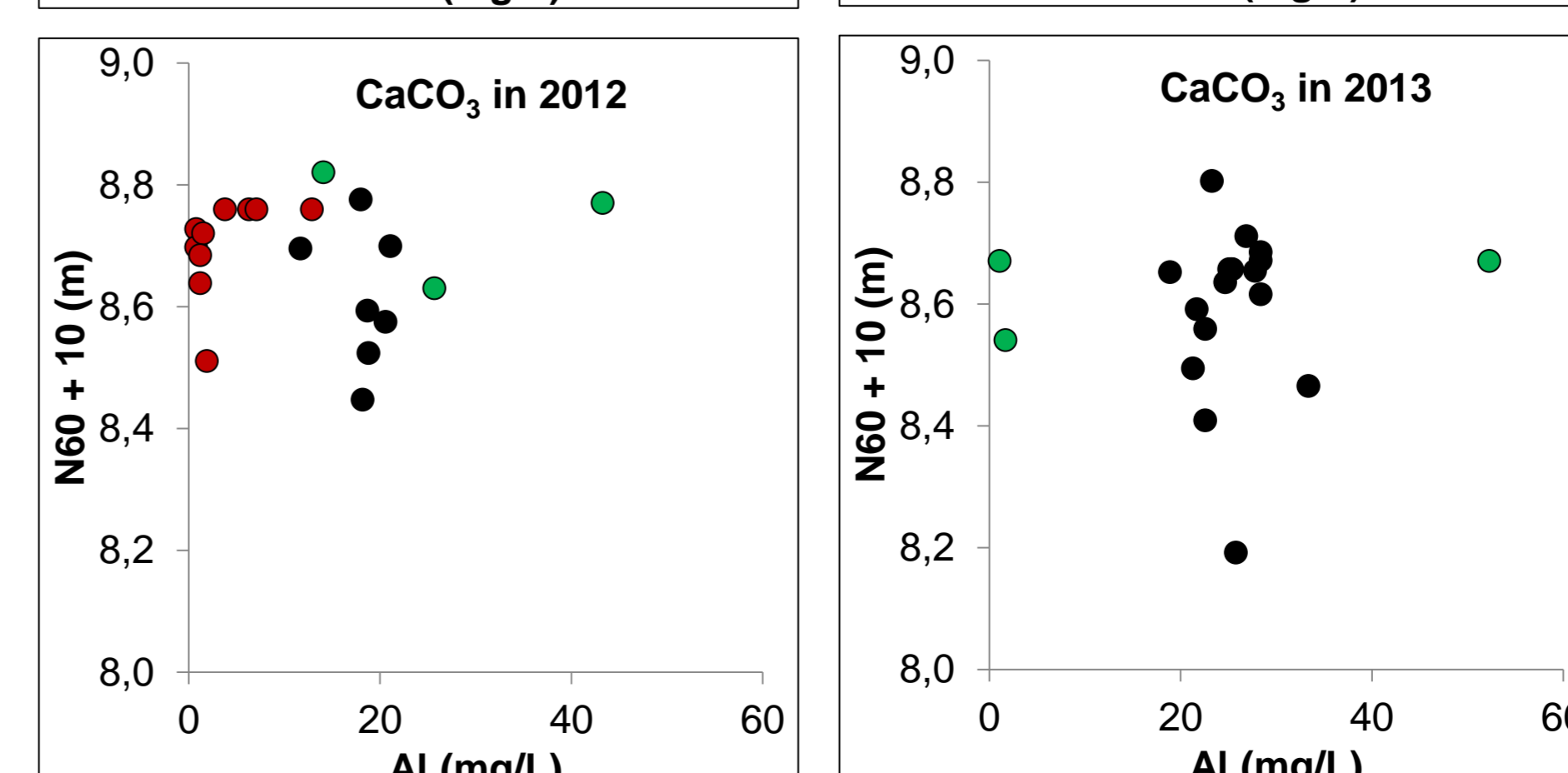


Figure 5. Aluminium concentrations vs. the groundwater level (N60 + 10 m) in the subfields before and after the treatments. Concentrations of Al were extremely high but decreased by c. 95 % with CaCO_3 treatment. Effects of Ca(OH)_2 treatments on Al-concentrations were relatively small.



References
Wu, Wong, Sten, Engblom, Österholm & Dopson, 2013. Microbial community responsible for acid and metal release from an Ostrobothnian acid sulfate soil, FEMS Microbiol. Ecol. 84, 555-563.