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Sustainable and profitable crop and livestock systems in south-central coastal Vietnam

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Editors: Surender Mann, Mary C. Webb and Richard W. Bell

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A survey of surface and groundwater quality contamination in south-central coastal Vietnam

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Abstract

Contamination of groundwater is posing a threat as a result of intensification of agriculture in south-central coastal (SCC) Vietnam. Increased use of chemical fertilisers on rice and vegetable crops and increased density of cattle around settlements are the main reasons for groundwater contamination. Villagers are dependent on groundwater and stream water as a supply for daily use and for crop irrigation. The risk of surface and groundwater contamination from nutrient run-off and leaching is likely to be high in coastal areas as the majority of the soils represent sands. However, few data exist to confirm this. The objective of this study was to collect and test water samples from various sources (bore wells, open wells, streams and irrigation canals) at different times of the year—mainly from An Chan commune, Tuy An district, Phu Yen province, where intensification of crops and livestock has taken place in recent years. Sampling was carried out from April 2011 to April 2012.

The results indicated that dissolved phosphate (PO_4^{3-}) and nitrate (NO_3^-) levels mainly met the criteria that are regulated for drinking water, at least to the minimum standard. However, in some samples of surface water for phosphate and surface and groundwater for nitrate, the levels were too high—up to 10.9 mg NO_3^-/L was found in stream/canal water, and up to 14 mg PO_4^{3-}/L and 50 mg NO_3^-/L in groundwater. These results confirm that contamination of surface and groundwater is a problem affecting An Chan commune and highlights the need to implement strategies to improve nutrient management on coastal sands in the SCC region. The outcomes from this study confirm that future detailed research is required to determine the sources of water contamination. Key sources are likely to include fertilisers applied to rice and vegetables, wastes from cattle and fisheries, and also human waste, due to lack of proper drainage systems in this region

Introduction

Population growth, along with rural and urban development, puts pressure on water resources through increasing demand and accelerates the rate of water pollution in affected areas. Such pressures are threatening the sustainability of water resources in south-central coastal (SCC) Vietnam but to date there has been limited study on the impacts of rural and urban development on groundwater quality in this region.

The sandy terrain with shallow unconfined groundwater that occurs along the coastal zone of SCC Vietnam is one such area where groundwater quality can be affected as a result of intensification of crops and livestock. Phu Yen province is a typical example. It lies on the coast and has a sandy terrain with an average annual rainfall of 1,800–2,100 mm. It has a short wet and long dry season and droughts are a regular feature of this region during summer.

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Similar rainfall patterns also occur in Khanh Hoa and Quang Nam provinces, while Binh Thuan and Ninh Thuan provinces, located at the southern end of SCC Vietnam, have an annual average rainfall of 700 mm.

An Chan is one of 15 communes belonging to Tuy An district, Phu Yen province. An Chan has a population of 9,243 spread over 13.53 km^2, with crops, livestock and fisheries as the main sources of income for the rural people. With an area of 682.4 hectares (ha), 50% of agricultural land in the commune is used for annual crops such as vegetables and rice (unpublished An Chan commune final report, December 2011). Farmers have small landholdings and are used to traditional farming practices. Apart from having poor fertility sandy coastal terrain, water resources have contributed to an agroecological zone characterised by shallow groundwater, wells, bores and run-off water. Such groundwater resources are unconfined and shallow, making them vulnerable to seawater intrusion and pollution from nutrient and agricultural chemical leaching.

Nutrient leaching occurs when accumulation of nutrients such as nitrate (NO_3^-) and phosphate (PO_4^{3-}) in the soil profile coincides with, or is followed by, a period of high irrigation or rainfall (Di and Cameron 2002). Thus, poor management of nitrogen (N) and phosphorus (P) fertilisers, manures and irrigation are likely to be primary sources of nutrient contamination in groundwater associated with the sands of SCC Vietnam. Increasing nitrate concentrations in groundwater were recorded in Ninh Thuan province within the regions where agricultural production had intensified (Keen et al. 2011). High nitrate levels in groundwater and surface water used for human consumption are of particular concern due to the serious health risk they pose (WHO 2011).

According to Australian guidelines (ARMCANZ and ANZECC 2000), the permissible nitrate concentrations in water should be less than 10 mg NO_3^-/L for drinking water. While phosphate is of less concern for drinking water, it does pose an environmental pollution risk, contributing to blue-algae blooms and growth of pathogens that pose a risk to human health. As is common in SCC Vietnam, groundwater is the main source of drinking water in An Chan commune, but the quality of this water is not known. With agriculture intensifying in An Chan and surrounding areas, it is likely that water quality is poor or at least in decline. In this chapter, we report on a water quality survey undertaken in An Chan between April 2011 and April 2012.

Materials and methods

The investigation was carried out for different water bodies, including surface water (in streams and agricultural irrigation canals) and groundwater (bore wells and open wells) in An Chan commune, Tuy An district, Phu Yen province, with particular reference to three villages in which the income of villagers is based mainly on agriculture and fisheries—namely, Phu Thanh, Phu Phong and Phu Quy villages.

The surface water collection points were chosen by elevation from upstream of the irrigation canal, and then by tracking the flow of the water downstream (Figure 1). Groundwater samples were collected from households with bore wells and open wells along a transect from west to east (Figure 1).

Samples of water were collected five times over 1 year from April 2011 to April 2012 . In the first year, timing of sampling was based on application of nutrients to crops to test their presence in different water bodies at crop harvesting periods, in April, May and November. In 2012, February and April were chosen for sampling water at the beginning and end of a crop season.

Samples were tested for electrical conductivity (EC), pH, phosphate and nitrate. The samples were filtered on site through a 0.45 mm cellulose acetate membrane filter, and kept in plastic vials in a cold container during transport to the laboratory for analysis. The level of phosphate was analysed using the ammonium molybdate spectrophotometer method (International Organization for Standardization (ISO) 6878:2004) and nitrate using the spectrometric method using sulfosalicylic acid at 415 nm wavelength (ISO 7890-3:1998 E).

The quality of water was assessed based on the parameters used for selection of the surface and groundwater resources in the water supply system (Table 1).

Results and discussion

Climate

The average temperature in this region remained between 25 and 29 °C throughout the study period. The main rainy season was between October and December and the rest of the period had low rainfall (Table 2). Evaporation was highest in May when the temperatures were highest.

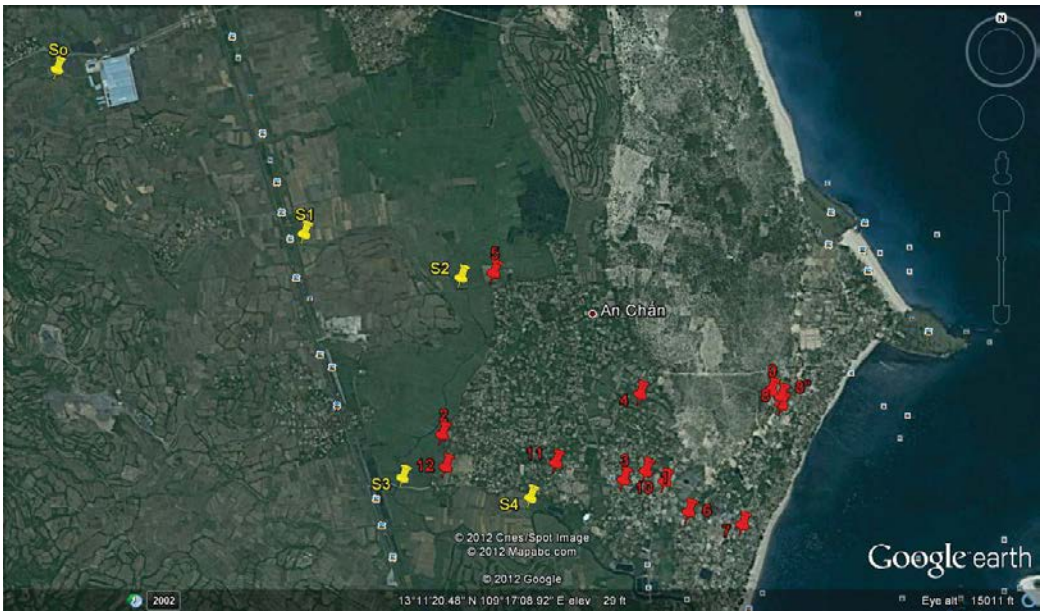

Figure 1. Sites for water samplings in An Chan commune, Phu Yen province, Vietnam. Note: yellow points indicate surface water sites and the red points refer to bore well and open well sites.

Table 1. Criteria for surface and groundwater quality

Level[a]	Parameters		
	pH	Nitrate (NO_3^-) (mg/L)	Phosphate (PO_4^{3-}) (mg/L)
A	6.5–8.5	0	0.0
B	6.0–9.0	<6	<1.5
C	>9.0 and <6.0	<10	<2.0

[a] A = good; B = medium; C = poor
Source: Vietnamese standard for water quality TCXD 233: 1999

Table 2. Average monthly temperatures, total monthly rainfall and evaporation in An Chan commune, Tuy An district, Phu Yen province, 2011–12

Date	Temperature (°C)	Rainfall (mm)	Evaporation (mm/day)
April 2011	26.0	128	90
May 2011	28.8	115	130
November 2011	26.0	308	69
February 2012	24.5	31	75
April 2012	27.9	152	89

Table 3. Values of pH and electrical conductivity (EC) for surface water and groundwater in An Chan commune, 2011–12

Water source	pH					EC (dS/m)				
	April 2011	May 2011	November 2011	February 2012	April 2012	April 2011	May 2011	November 2011	February 2012	April 2012
Streams/canals	7.6	8.0	7.6	7.8	7.4	0.863	1.207	0.292	0.338	0.331
Open wells	7.1	7.0	7.2	7.6	7.3	0.516	0.509	0.345	0.394	0.400
Bore wells	7.3	–	7.3	7.6	7.2	0.750	–	0.631	0.289	0.601

pH and electrical conductivity

The pH of water was neutral at all times of sampling (Table 3) and was within the range specified for drinking water (Table 1). The EC was a bit higher during April–May 2011 compared with other times of sampling; however, the values were still in the acceptable range. Higher concentrations of salts in the water as a result of the dry period may have been the cause of elevated EC levels. Lower EC levels during November–February—the main rainy season, when the watertable is almost at the surface—were the result of dilution.

Nitrate

Surface water quality

Samples were taken from upstream to downstream following the gradient of water flow of the irrigation canal. The sampling points are shown in Figure 1. The lowest values of nitrate were recorded in February 2012, while the highest values were recorded in November 2011 (Figure 2). Almost all samples were within the acceptable range (level A or B in Table 1). There was no clear pattern in nitrate concentrations along the gradient of the water flow of the canal. A rapid change from 2.7 mg NO_3^-/L to an unacceptably high 10.9 mg NO_3^-/L was recorded in November 2011 between the first and second sampling points. 2011 was a year of relatively low rainfall and this may have been the cause of high nitrate levels. In addition, nitrogen fertiliser applied to crops adjacent to the canal may have been the cause of high nitrate levels as intensification of crops requires regular application of fertilisers.

Groundwater quality

Values of nitrate in open wells and bore wells varied significantly in the study area. Both types of wells are used for irrigation and to meet water requirements for daily household activities. Open wells had

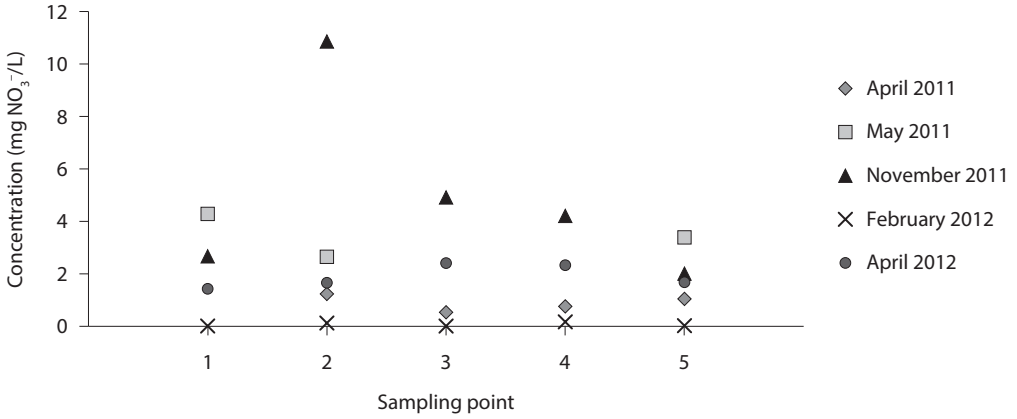

Figure 2. Nitrate-nitrogen level in surface water in An Chan commune, 2011–12. Note: there was no water in sampling points 3 and 4 in May 2011 (hence, no data).

acceptable as well as high nitrate levels (classed as level C, Table 1) in quality (Figure 3). Bore wells had the same pattern as open wells but some of their values reached as high as 50 mg NO_3^-/L (Figure 4). Higher rainfall in some months may have diluted nitrate concentrations in open wells more than in bore wells, and/or the greater depth of open wells (5 m) compared with bore wells (4 m) may contribute to variability in nitrate levels.

Phosphate

Concentrations of phosphate in both surface water and wells are shown in Figures 5 and 6. Streams and canals (surface water) had acceptable levels of phosphate (<2 mg PO_4^{3-}/L). However, both open wells and bore wells had higher levels of phosphate (8–14 mg PO_4^{3-}/L) during April 2012, which reflects the impact of the dry season.

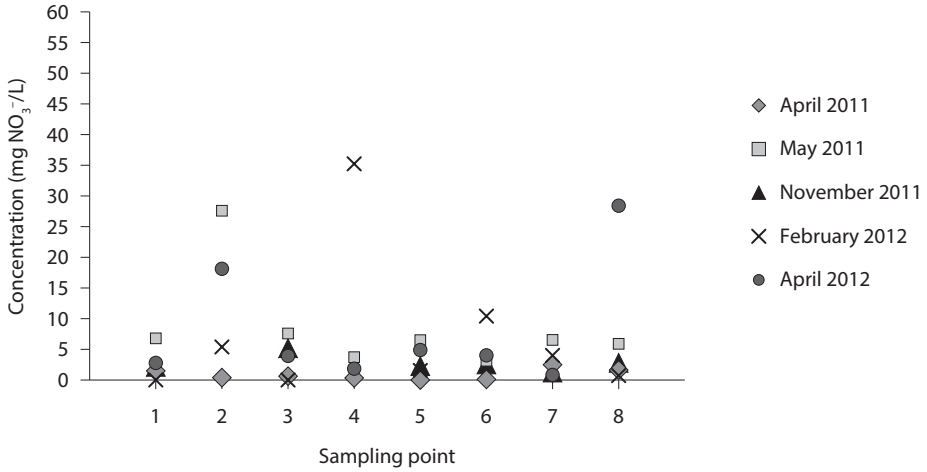

Figure 3. Open well water nitrate concentrations, 2011–12

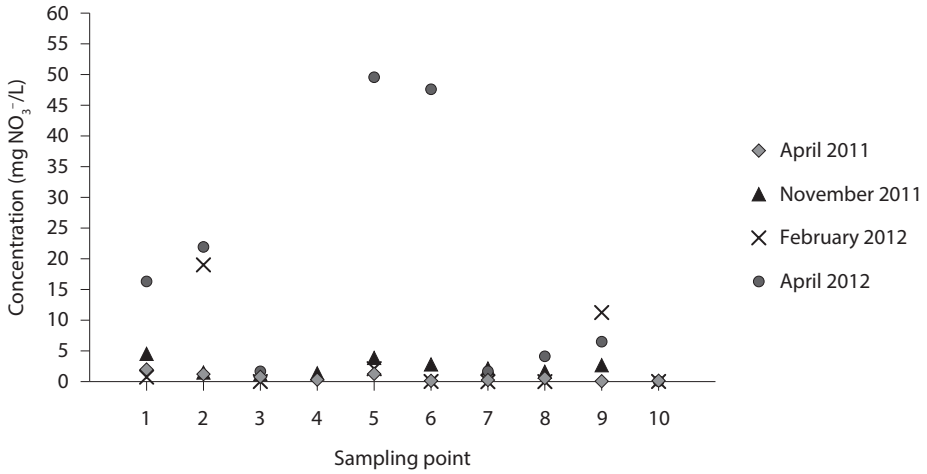

Figure 4. Bore well water nitrate concentrations, 2011–12

Water in open wells had higher levels of phosphate than in bore wells throughout the sampling period and were often much higher than the recommended limits for drinking water of 2 mg PO_4^{3-}/L (Figure 6). Most open wells have clear water while bore wells are sometimes muddy; hence, people prefer to use open wells rather than bore wells. However, based on these results, bore wells have a better water quality than open wells in terms of phosphate content.

The survey period was too short to draw long-term conclusions. In addition, one would have assumed that the trend for phosphate and nitrate levels would

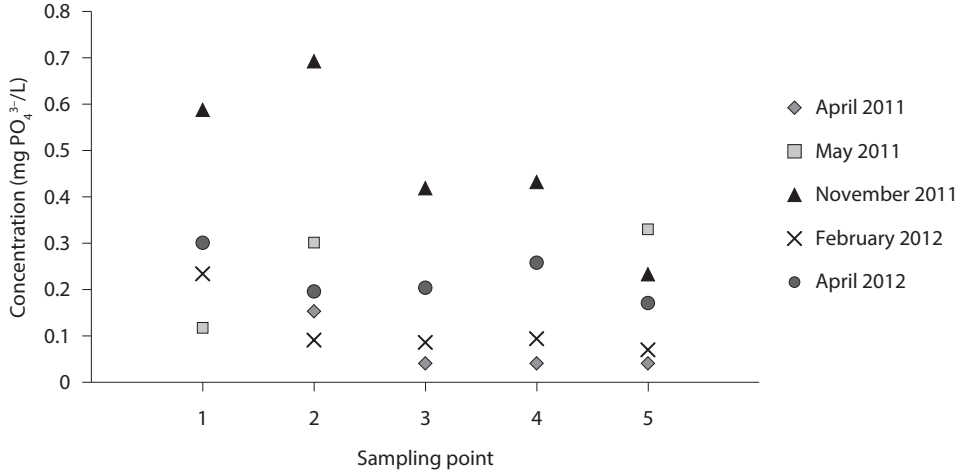

Figure 5. Phosphate concentration in surface water, 2011–12

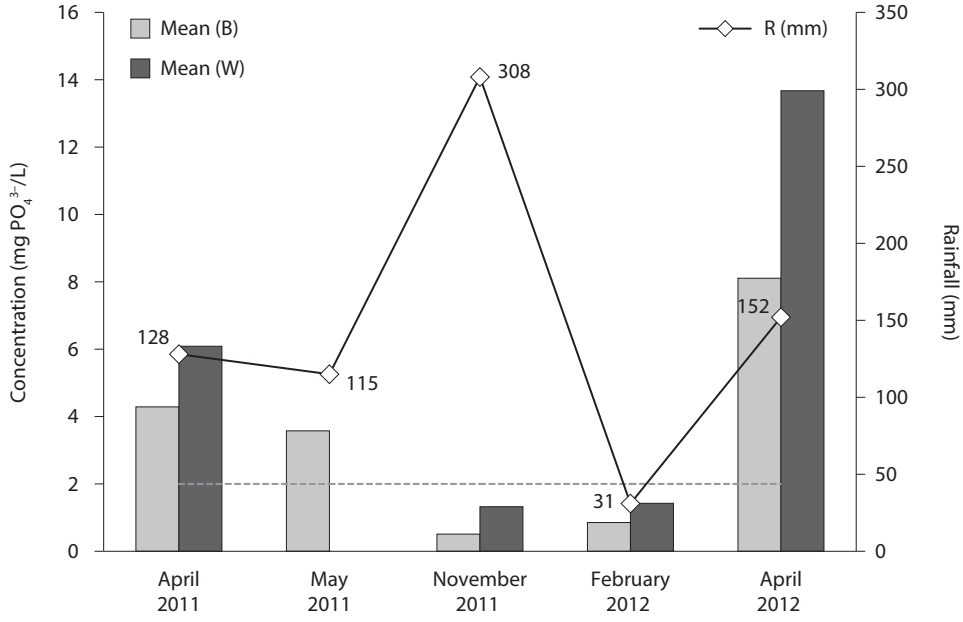

Figure 6. Concentration of phosphate in open (O) wells and bore (B) wells, 2011–12. Note: open wells were not sampled in May 2011

have been similar. This poses the question of whether the analytical techniques used for measuring phosphate and nitrate were appropriate, as quality control has been an issue with most of the laboratories in Vietnam. Nonetheless, in-depth study needs to be carried out in the coastal regions where sandy soils dominate the landscape and intensification of crops and livestock is increasing rapidly. As a result of intensification of crops, higher doses of fertilisers are applied regularly, particularly for vegetable crops.

Increasing numbers of livestock housed adjacent to the houses over sandy soil pose a further risk of contamination of groundwater as a result of faecal and urine disposal. Nitrate and phosphate leaching in sandy soils is a common feature due to low cation and anion exchange capacity (Bell et al. 2015).

Previous studies carried out in Ninh Thuan, another of the provinces of SCC Vietnam, also found higher levels of nitrates in water (Keen et al. 2011), suggesting that all areas within the SCC region need to be surveyed and monitored for water quality.

Conclusion

The concentrations of nitrate and phosphate indicated some water contamination in shallow groundwater sampled from open and bore wells in An Chan commune. The values of up to 50 mg NO_3^-/L and 14 mg PO_4^{3-}/L were found in some of the samples raising concern about the quality of water consumed by the community in An Chan in particular, Phu Yen province in general, and in other coastal regions. Further research is required to pinpoint the source of nutrient pollution, especially in the SCC region.

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