Report on recent national ICP IM activities in Sweden 2013 - 2015

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Introduction

The Swedish integrated monitoring programme is run on four sites distributed from south central Sweden (SE14 Aneboda) over the middle part (SE15 Kindla), to a northerly site (SE16 Gammtratten). The long-term monitoring site SE04 Gårdsjön F1 is complementary on the inland of the West Coast and has been influenced by long-term high deposition loads. The sites are well-defined catchments with mainly coniferous forest stands dominated by bilberry spruce forests on glacial till deposited above the highest coastline. Hence, there has been no water sorting of the soil material. Both climate and deposition gradients coincide with the distribution of the sites from south to north (Table 1). The forest stands are mainly over 100 years old and at least three of them have several hundred years of natural continuity. Until the 1950's, the woodlands were lightly grazed in restricted areas. In early 2005, a heavy storm struck the IM site Aneboda, SE14. Compared with other forests in the region, however, this site managed rather well and roughly 20-30% of the trees in the area were storm-felled. In 1996, the total number of large woody debris in the form of logs was 317 in the surveyed plots, which decreased to 257 in 2001. In 2006, after the storm, the number of logs increased to 433, corresponding to 2711 logs in the whole catchment. In later years, 2007-2010, bark beetle (*Ips typographus)* infestation has almost totally erased the old spruce trees. In 2011 more than 80% of the trees with a breast height over 35 cm where dead (Löfgren et al., 2014) and currently almost all spruce trees with diameter of ≥20 cm are gone.

Table 1. Geographic location and long-term climate at the Swedish IM sites.

	SE04	SE14	SE15	SE16
Latitude; Longitude	N 58° 03′; E 12° 01′	N 57° 05′; E 14° 32′	N 59° 45′; E 14° 54′	N 63° 51′; E 18° 06′
Altitude, m	114-140	210-240	312-415	410-545
Area, ha	3.7	18.9	20.4	45
Mean annual temperature, °C	+6.7	+5.8	+4.2	+1.2
Mean annual precipitation, mm	1000	750	900	750
Mean annual evapotransporation, mm	480	470	450	370
Mean annual runoff, mm	520	280	450	380

In the following, climate, hydrology, water chemistry and some ongoing work at the four Swedish IM sites are presented (Löfgren, 2015).

Climate and Hydrology in 2013

In 2013, the annual mean temperatures were similar to the long-term mean (1961-1990) for the two southern sites, while the two northern sites had approximately one degree higher annual means. Compared with the measured time series, 14 years at site SE16 and 18 years at the other sites, the temperatures in 2013 were on average for the two northern sites but somewhat higher at the southern sites. This resembles the year 2010 when temperatures mainly were lower than normal. Low temperatures were observed in 2010 and 2012 while 2011 show higher temperatures. Variations between years have been considerable, especially for the last five years with up to three degrees. Smaller variations were seen at the central site SE 15 Kindla with only one degree.

Precipitations in 2013 showed lower values compared to the long-term average (1961-1990). For site SE04 Gårdsjön the amount was 51 mm (5%) lower, at SE14 Aneboda the deviation to normal was 193 mm (26%), for SE15 Kindla 225 mm (25%) and the northern site SE16 Gammtratten showed 129 mm (18%) lower than the long-term mean. In 2012, precipitation was higher than the long-term average with 3-44% for the four sites. Also 2011, the two southern sites had higher precipitation (SE14: 7% and SE04: 25%), while the sites further north only reached approximately 70% of the long-term averages.

The characteristic annual hydrological patterns of the catchments are for the southern sites high groundwater levels during winter and lower levels in summer and early autumn. Evapotranspiration has decisive influence on the runoff pattern. In 2013, these patterns were fairly typical, especially for the two northern sites. The two southern sites showed also comparably normal discharge patterns but with a tendency to a small spring flow peak, related to a cold early spring followed by rather high rainfall furnishing high discharge (Figure 1).

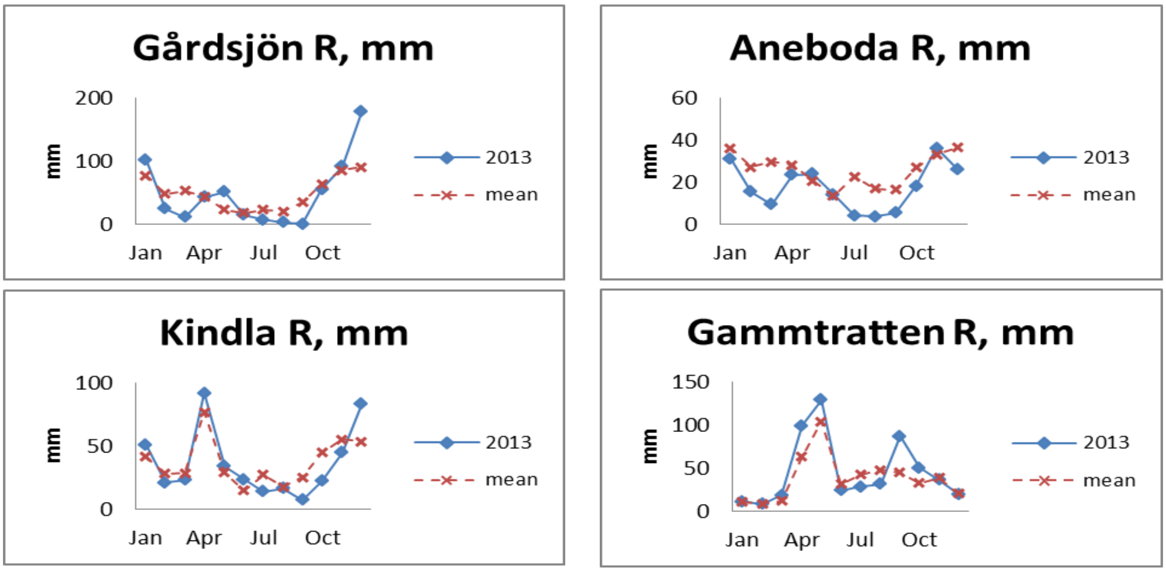

Figure 1. Discharge patterns at the Swedish IM sites in 2013 compared to monthly averages for the period 1996 – 2013 (mean). Note the different Y-axis scales.

At the two northern sites, generally snow accumulates during winter and groundwater levels stay low furnishing low discharge. However, warm periods in the winter period with temperatures above 0 °C have during a number of years contributed to snowmelt and runoff also in the winter period. As a consequence, spring discharges have been comparably low in the snowmelt period deviating from conditions three decades ago.

In 2013, high runoff was observed in December at SE04 Gårdsjön and SE15 Kindla due to high precipitation and warm weather. Annual runoff 2013, made up 40-88% of the annual precipitation, which is comparable to the 40-60% found during previous years. A higher proportion was found at the northern site Gammtratten (SE16), where a rather high snowmelt flood provided high discharge together with a runoff peak in early autumn. In the north, cold climate yields low evapotranspiration (12%) and consequently provided high runoff (Table 2). At site Aneboda (SE14), the storm-felling and bark beetle attacks have reduced the forest canopy cover and thereby followed low interception but total evapotranspiration was anyhow fairly high.

Table 2. Compilation of the 2013 water balances for the four Swedish IM sites.
P – Precipitation, TF – Throughfall, I - Interception, R – Water runoff.

	Gårdsjön SE04		Aneboda SE14		Kindla SE15		Gammtratten SE16	
	mm	% of P	mm	% of P	mm	% of P	mm	% of P
Bulk precipitation, P	966	100	528	100	874	100	614	100
Throughfall, TF	707	73	538	102	468	54	591	96
Interception, P-TF	259	27	-10	<0	407	47	23	4
Runoff, R	590	61	212	40	435	50	542	88
P-R	376	39	316	60	439	50	72	12

Water chemistry in 2013

Low ion concentrations in bulk deposition and throughfall characterise the three inland sites (electrolytical conductivity = 1-2 mS m^{-1}), while sea salt provides higher ionic strength at the west coast SE04 site (5.6 mS m^{-1} ; throughfall). Water pathways through the catchment soils are fairly short and shallow, providing rapid surface water formation from infiltration to surface water runoff. The acidity in deposition was similar at all sites with somewhat higher pH (0 - 0.1 units) in throughfall (TF) compared with bulk deposition (BD). The Gårdsjön site SE04 deviated from this pattern and pH in TF was 0.1 units lower compared to BD. As the years before, pH was slightly higher than 5.0 in BD at most sites in 2013 (Table 3).

Table 3. Deposition chemistry 2013 at the four Swedish IM sites. S and N in kg, ha^{-1} yr^{-1}.

	SE04	SE14	SE15	SE16
pH, bulk deposition	5.4	5.2	5.1	5.1
pH, throughfall	5.3	5.4	5.1	5.2
SO_4-S, bulk deposition	3.5	1.9	1.8	1.1
N-tot, bulk deposition	8.5	6.3	4.3	2.5

During the water passage through the catchment soils, organic acids were added and leached to the stream runoff, buffering at a pH between 4.5-4.8 at the three southern sites. At SE14, pH in stream water was 4.7 compared with 5.2 in bulk deposition. In the stream, ANC was approximately 0.07 meq L^{-1} as a consequence of high concentrations of DOC (≈22 mg L^{-1}). This could be compared with SE15 with an ANC of 0.01 meq L^{-1} mainly coupled to low DOC concentrations (≈10 mg L^{-1}). At the northern site SE16, ANC (≈0.1 meq L^{-1}) was to a large extent related to bicarbonate alkalinity, buffering the stream water at a pH of ca 5.6.

During the period 1996 to 2010, sulphur deposition decreased by 2-7 kg S ha^{-1} yr^{-1} and pH increased with 0.3-0.5 pH-units except for at the northernmost site Gammtratten with small changes in pH. For all four sites, outflow of S were 2-3 times higher compared to deposition.

Besides ANC and pH, the stream water chemistry is to a considerable extent influenced by organic matter. At Aneboda site (SE14), the DOC concentration was high with 22 mg L^{-1} while the other sites Gårdsjön (SE04), Kindla (SE15) and Gammtratten (SE16) showed lower values on 15, 10 and 9 mg L^{-1}, respectively. High DOC concentrations create prerequisites for metal complexion and transport as well as high organic nitrogen fluxes. The organic nitrogen concentrations in stream water ranged 0.19-0.52 mg N L^{-1}. In nitrogen budgets for catchments, transformation of inorganic nitrogen in deposition to surface runoff organic nitrogen needs consideration. At site Aneboda, the inorganic nitrogen was 0.30 mg N L^{-1}, which was high compared with the other sites where the concentrations were below 0.05 mg N L^{-1}. The high inorganic nitrogen concentrations at Aneboda are related to the forest die back.

Aluminum, toxic to fish and other gill breathing organisms in the inorganic form, has been analyzed in soil solution, groundwater and surface waters at the IM sites. Rather high concentrations occurred in the soil solution (0.2-1.4 mg L^{-1}) as well as in stream water (0.5-0.6 mg L^{-1}) at the three southern sites with low pH (4.5-4.8). At the northern site SE16 with a pH of 5.6, the aluminum concentrations were comparably low on approximately 0.2 mg L^{-1}. Inorganic Al made up 19-43% at the four sites, corresponding to 0.12 – 0.24 mg Ali L^{-1} at the three southern sites with low pH and 0.04 mg Ali L^{-1} at the northern site Gammtratten. Those levels are considered extremely high at the three southern sites and high in the north, according to the SEPA classification. The priority heavy metals Pb, Cd and Hg were still accumulating in the catchment soils, while the concentrations were on the lower levels as concerned biological effects. However, methyl mercury was still exerting hazardous concentrations for limnic life.

Highlights from the Swedish Integrated Monitoring

In the national IM report for 2015, Löfgren (2015) summarized a scientific article published in Ambo (Löfgren et al. 2014), which is referred to below.

Storm felling and bark beetle attack – effects on forest and nitrogen dynamics

In January 2005 the Swedish IM site SE14 Aneboda in southern Sweden was struck by the heavy storm Gudrun (max wind on 33 m s^{-1}) and 15-20% of the trees were wind-thrown. Later, in 2008 bark beetle (*Ips typographus* L.) infestation occurred and most big trees were affected resulting in almost no living Norway spruce trees with a breast height diameter over 20 cm (Fig. 2) in the 2011 inventory.

The forest die-back effects on the nitrogen concentrations were local and limited in soil water and groundwater. Total nitrogen in stream water didn't change very much either and the N_{tot} leaching reached 2.1 kg ha^{-1} yr^{-1} as a mean for the period 2005-2012 compared with the mean 1.9 kg ha^{-1} yr^{-1} for the period before the storm (1997-2004). However, inorganic nitrogen, i.e. the NO_3-N and NH_4-N concentrations reached up to 0.5 mg L^{-1} and 0.1 mg L^{-1}, respectively, while being about 0.05 mg L^{-1} before the storm. Runoff in stream water increased from approximately 0.1 kg ha^{-1} yr^{-1} and 0.05 kg ha^{-1} yr^{-1}, respectively, before the storm to 0.1 – 1.1 kg NO_3-N ha^{-1} yr^{-1} and 0.05-0.1 kg NH_4-N ha^{-1} yr^{-1} after the event.

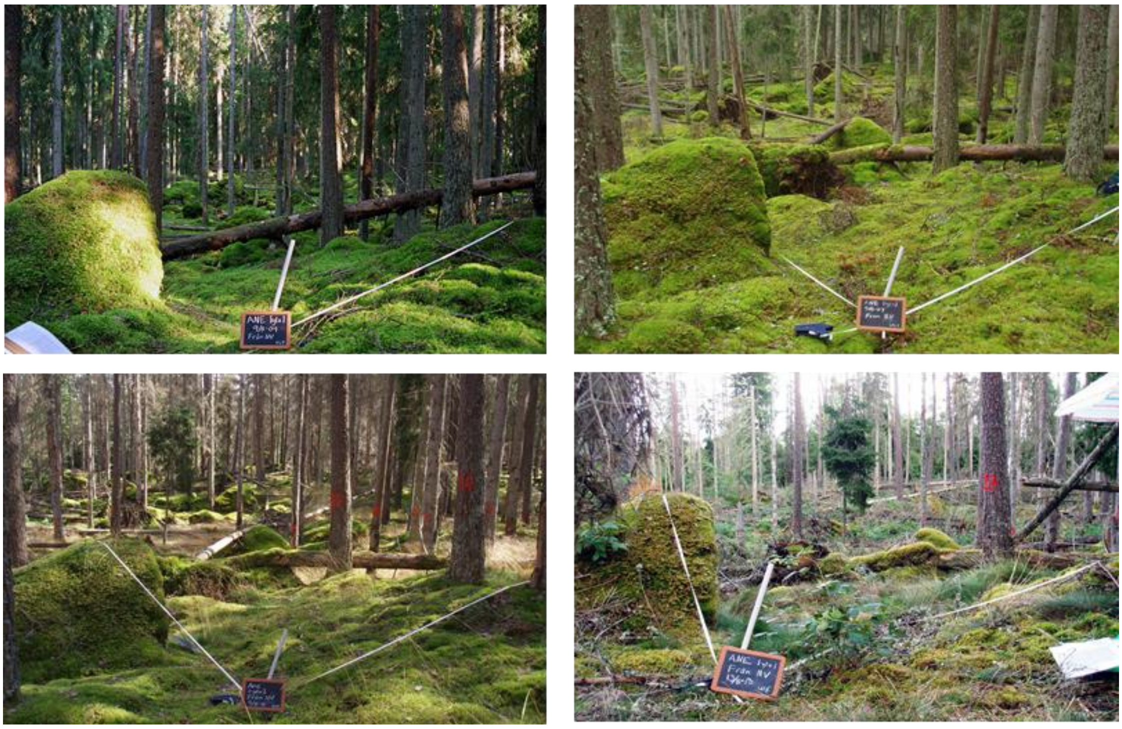

Figure 2. The intensive vegetation plot no 1 viewed from the northwest corner in the middle of August in 2004 (upper left), 2007 (upper right), 2010 (lower left) and 2013 (lower right). The major storm Gudrun hit the area in January 2005 and the bark beetle infestation became visible in 2008. Photo: Ulf Grandin, SLU

Healthy forest ecosystems provide environmental services

In the Swedish national report, the importance to maintain ecosystem functions to support environmental services such as clean air, healthy soil, high water quality and food supply was addressed. To reach this, there are needs to make further efforts to mitigate air pollution, preserving biodiversity and limit climate change.

References

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