Annex I

Report on National ICP IM activities in Sweden in 2016

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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 were 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 and hydrology 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 in 2016 are presented (Löfgren 2017).

Climate and Hydrology in 2016

In 2016, the annual mean temperatures were higher (0.4–1.4 °C) compared to the long-term mean (1961–1990) for all four sites. Largest deviation occurred at the northern SE16 site. Compared with the measured time series, 16 years at site SE16 and 20 years at the other sites, the temperatures in 2016 were somewhat higher at all the IM sites. These values were slightly lower than in 2014 and 2015 when temperatures were the highest observed for the whole measurement period with exception for SE15 Kindla where the temperature was slightly higher in the years 1999 and 2000. The variations between years have been considerable, especially for the last five years, over 3 °C at three of the sites. Smaller variations were found at the central site SE15 Kindla, only 1 °C.

Compared to the long-term average values (1961–1990), the precipitation amounts in 2016 were much lower at three of the sites with up to 171 mm at SE14 Aneboda corresponding to 77% of the long-term average. For SE16 Gammtratten in the north, this value was 131 mm (81 %) and at the central site SE15 Kindla, it was 71 mm (92%). Only at site SE04 Gårdsjön, the precipitation amount was on average. Especially the summer and autumn precipitation was low.

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. In 2016 at SE14 Aneboda, high groundwater levels were observed in February and thereafter successively lowered until late autumn when the aquifers started to be refilled. For SE16 Gammtratten in the north, snowmelt occurred in April–May with the highest groundwater levels in the end of May. After that the water level was subsiding until next spring. At site SE15 Kindla, a more varying pattern was observed with several peaks 0.2 m below the soil surface during February to May. Summer rains also created groundwater peaks, but the lowest levels, close to one meter below soil surface, were found in late summer. The aquifer was refilled in November. The patterns were fairly similar to those in 2015. The groundwater level has decisive influence on the discharge values (Fig. 1).

In addition to precipitation, evapotranspiration affects the runoff pattern. In 2016, the runoff pattern was fairly typical for SE16 Gammtratten with a marked snowmelt peak in May. The sites SE04 Gårdsjön and SE15 Kindla showed fairly typical patterns during the first 6 months followed by unusually low discharges in July to October due to low precipitation. In November, ordinary discharge levels occurred. For SE14 Aneboda low discharge was observed from April/May throughout the rest of the year, reflecting the very low discharge and lake water levels found in the southern part of Sweden this year (Fig. 1).

At the two northern sites, generally snow accumulates during winter and the groundwater levels stay low furnishing low discharge. However, warm winter periods with temperatures above 0 °C have during a number of years contributed to snowmelt and excess runoff also during this season. As a consequence, the spring discharges have been comparably low during snowmelt, deviating from the normal conditions. In 2016, the central and northern sites SE15 Kindla and SE16 Gammtratten, respectively, showed relatively normal winter and spring runoff patterns (Fig. 1).

In 2016, the annual runoff made up 31–83% of the annual precipitation, which was a wide range compared to the ordinary 40–60% found in previous years. The highest share was found at the northern site SE16 Gammtratten (83%), due to a rather intense snowmelt period and fairly cold climate during the rest of the year, yielding low evapotranspiration (17%) and high runoff (Table 2). At site Aneboda (SE14),

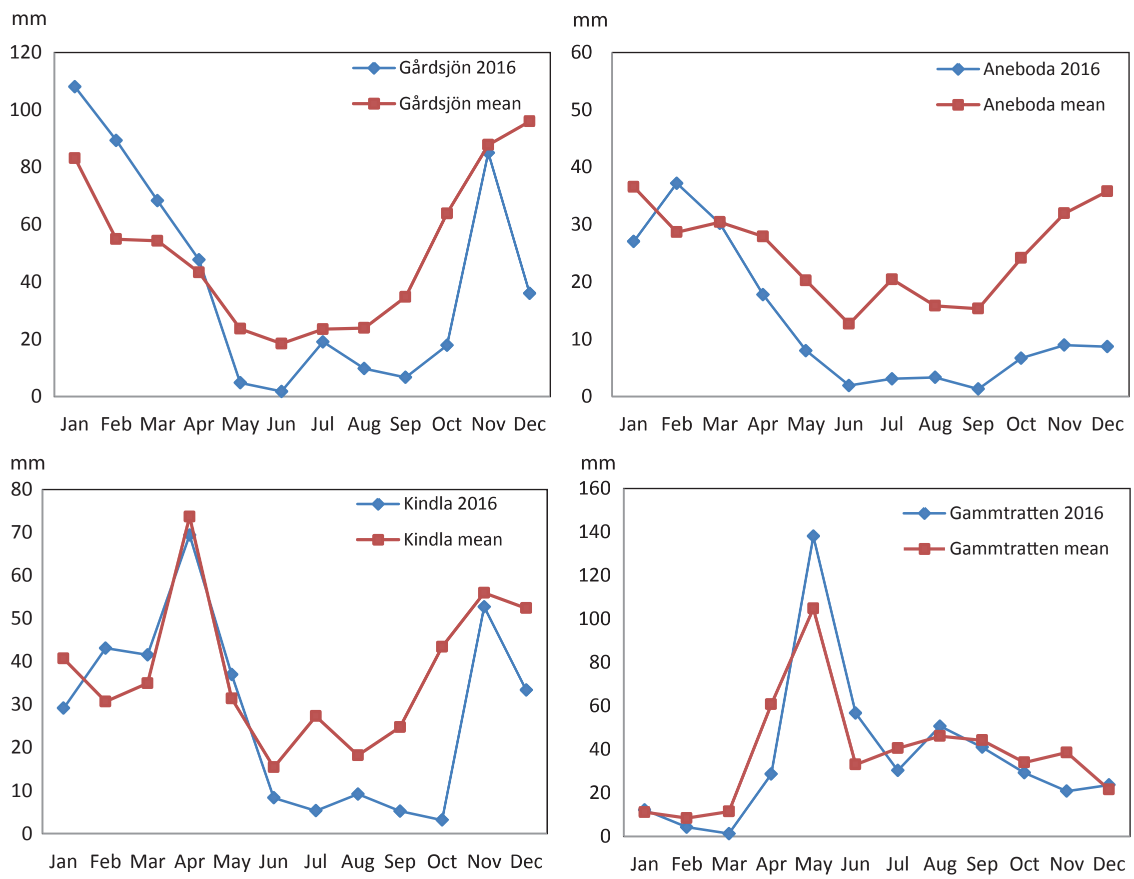

Figure 1. Discharge patterns at the Swedish IM sites in 2016 compared to monthly averages for the period 1996–2016 (mean). Note the different Y-axis scales.

storm felling, followed by bark beetle attacks, have reduced the forest canopy cover, inducing low interception. Actually, the measured throughfall reached 89% of precipitation. The total evapotranspiration was estimated to 349 mm, a value lower than in the previous years.

At SE04 Gårdsjön, evapotranspiration and runoff were equally large, each constituting 50% of the precipitation (Table 2), which deviates from earlier years when runoff often made up 2/3. At SE15 Kindla, the annual runoff was 337 mm, which was fairly low compared to the 30 years long-term mean of 450 mm and compared to the mean of the monitoring period of 449 mm (Table 2). Low precipitation with 823 mm resulted in 486 mm evapotranspiration, i.e. 69% of precipitation, a rather high value despite a high throughfall on 655 mm.

Table 2. Compilation of the 2016 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	975	100	503	100	823	100	525	100
Throughfall, TF	757	78	449	89	655	80	557	106
Interception, P–TF	218	22	54	11	168	20	-32	-4
Runoff, R	494	51	154	31	337	41	436	83
P–R	481	49	349	69	486	59	89	17

Water chemistry in 2016

Low ion concentrations in bulk deposition (electrolytical conductivity = 1–2 mS m^{-1}) characterise all four Swedish IM sites. The concentrations of ions in throughfall, including dry deposition, were higher at three sites. At SE16 Gammtratten, the conductivity in throughfall (1 mS m^{-1}) was almost the same as in bulk deposition indicating very low sea salt deposition and uptake of ions by the trees. At the two most southern sites, sea salt deposition provides tangibly higher ion concentrations, especially at the west coast SE04 Gårdsjön site (6.5 mS m^{-1} in throughfall). The catchments groundwater pathways are fairly short and shallow, providing rapid surface water formation from infiltration to surface water runoff. However, conductivity in the soil water was higher compared to throughfall, showing influences from evapotranspiration and soil chemical processes. The acidity in deposition has during the last 10 years been rather similar at all sites with somewhat higher pH values (0–0.5 units) in throughfall compared with bulk deposition. However, in 2016 SE04 Gårdsjön had a throughfall pH on 5.1 while the two sites SE14 Aneboda and SE15 Kindla had values on 5.3 (Table 3). For SE16 Gammtratten, pH values were 4.8 and 4.9 in bulk deposition and throughfall, respectively.

Table 3. Mean deposition chemistry values 2016 at the four Swedish IM sites.
S and N in kg ha^{-1} yr^{-1}.

	SE04	SE14	SE15	SE16
pH, bulk deposition	4.9	4.9	5.4	4.8
pH, throughfall	5.1	5.3	5.3	4.9
S, bulk deposition	3.5	1.8	1.3	0.8
N, bulk deposition	7.6	6.7	3.9	2.2

During the water passage through the catchment soils, organic acids were added and leached to the stream runoff. In the upslope recharge areas, pH in the upper soil layers (E-horizon) was mainly lower than in throughfall. However, in the peat in discharge areas at SE15 Kindla and SE16 Gammtratten, pH was higher compared to throughfall while it was similar to throughfall at SE14 Aneboda, but considerably lower at SE04 Gårdsjön with a pH of 4.4. In the recharge areas, the buffering capacity in soil water and groundwater varied between negative and positive values, but were most frequently on the negative side, especially for SE15 Kindla. In the discharge areas, the buffering capacity in groundwater was fairly high with ANC exceeding 0.14 mEq L^{-1} at SE14 Aneboda and SE15 Kindla and with bicarbonate (HCO_3^-) present at Aneboda, Kindla and Gammtratten at average concentrations of 0.02, 0.14 and 0.20 mEq L^{-1}, respectively. At SE04 Gårdsjön ANC was lower (0.03 mEq L^{-1}). The stream waters were acidic with pH values below 4.8 at all sites except Gammtratten having a pH of 5.6. The stream water buffer capacity was positive at all sites, even though SE04 Gårdsjön and SE15 Kindla had an ANC close to 0 mEq L^{-1}. Anions of weak organic acids contributed to the positive ANC and bicarbonate contributed at SE16 Gammtratten.

The share of major anions in deposition was similar for sulphate, chloride and nitrate at three of the sites, while chloride dominated at SE04 Gårdsjön due to the proximity of the sea. In throughfall, organic anions contributed significantly at all four sites. The chemical composition changed during the catchment soils passage and the sulphate concentrations were higher in stream water compared with deposition, indicating desorption or mineralization of previously accumulated sulphur in the soils. At Aneboda, nitrification contributed to fairly high nitrate values in the recharge area soil water (0.03–0.46 mEq L^{-1}), but was considerably lower in the discharge areas, probably due to nitrogen uptake and denitrification.

Besides effects on ANC and pH, the stream water chemistry is to a considerable extent influenced by organic matter. At Aneboda (SE14), the DOC concentration was high with 24 mg L^{-1} while the other sites Gårdsjön (SE04), Kindla (SE15) and Gammtratten (SE16) showed lower values 13, 11, and 10 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 from 0.20 to 0.63 mg N L^{-1}. The shares of Norg/Ntot were 70–90%, showing Norg dominating Ntot, and with SE14 Aneboda having the lowest share and SE16 Gammtratten and SE15 Kindla on the highest range. Inorganic nitrogen (NO_3-N and NH_4-N) was low at three sites with <0.48 mg L^{-1} but higher at SE14 Aneboda with 119 mg L^{-1}, possibly due to the forest damage.

Total phosphorus (Ptot) in bulk deposition varied between 2 µg L^{-1} and 16 µg L^{-1} with the highest values at SE14 Aneboda. In stream water, SE14 Aneboda also showed the highest Ptot (33 µg L^{-1}) as well as DOC concentrations. The other sites had average Ptot concentrations between 3 µg L^{-1} and 9 µg L^{-1} with the highest value at SE16 Gammtratten.

Inorganic aluminum (Al_i), toxic to fish and other gill-breathing organisms, has been analyzed in soil solution, groundwater and surface waters at the IM sites. Relatively high total Al concentrations occurred in the soil solution (0.4–1.8 mg L^{-1}) as well as in stream water (0.25–0.50 mg L^{-1}) at the southern sites Aneboda and Kindla with low pH (ca 4.8). At the northern site SE16 with a pH of 5.6, the total Al concentrations were low, approximately 0.25 mg L^{-1}. Inorganic Al made up 16–46% of the total Al at the three sites (data from 2016 lacking for Gårdsjön), corresponding to 0.04–0.26 mg Al_i L^{-1} with high Al_i at low pH, and the 0.04 mg Al_i L^{-1} at the northern site Gammtratten with higher pH. According to the SEPA classification system, the Al_i concentrations at Aneboda and Kindla are considered extremely high and high at Gammtratten. The priority heavy metals Pb, Cd and Hg were still accumulating in the catchment soils, while the stream concentrations were low compared with the levels causing biological effects. However, methyl mercury, only measured at Aneboda, was still relatively high creating prerequisites for bioaccumulation. In stream water Hg-tot concentration was 8.2 ng L^{-1} with Hg-methyl on 2.2 ng L^{-1}.

In summary, the four Swedish IM sites show low ion contents and permanently acidic conditions. In stream water, only the northern site SE16 Gammtratten had buffering capacity related to bicarbonate alkalinity. Organic matter has an impact on the water quality with respect to colour, metal complexation, and phosphorus concentrations at all sites, but less at SE15 Kindla, where rapid soil water flow paths provide low DOC and acidic waters. For SE14 Aneboda, the forest dieback provides a relatively high share of water runoff as well as high nitrate concentrations compared with the other three sites. SE04 Gårdsjön is strongly influenced by the sea.

References

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