Sveriges lantbruksuniversitet
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ALTERNATIV TILL GRÄSMATTA I SVERIGE FRÅN TEORI TILL PRAKTIK

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INNEHÅLL

INLEDNING

Gräsmattan, den klippta gräsytan, är ett av de mest dominerande och synliga inslagen i urbana grönområden världen över. Gräsmattor levererar många viktiga ekosystemtjänster, samtidigt är de dyra i drift och medför att ändliga resurser förbrukas. Det finns också forskning som visar att gräsmattorna bidrar till att stadsmiljöer världen över blir alltmer likformiga (Ignatieva, 2010) (figur 1). Det är därför nödvändigt att kritiskt utvärdera dessa ytor och att försöka utveckla alternativa lösningar. Samtidigt som vi rekommenderar en granskning, inser vi att många viktiga värden är kopplade till gräsmattan. Vidare vill vi att läsaren använder sitt kritiska tänkande och sunda förnuft när det gäller anpassningen av våra rekommendationer till de sociala och fysiska förhållanden som råder lokalt, där rekommendationerna ska tillämpas.

Figur 1. Gräsmattor bidrar till att stadsmiljöer i olika delar av världen blir mer lika varandra, trots olika klimat. Överst vänster: Gräsmattor i Dubai (Förenade Arabemiraten, ökenklimat), Mumbai (Indien, tropiskt klimat), Tokyo (Japan, fuktigt tempererat klimat) och Malmö (Sverige, tempererat klimat). Foto: M.Ignatieva.

Definitionen på en gräsmatta

Trots att gräsmattor är så vanliga finns det begränsat med forskning i hur man definierar en gräsmatta. De flesta studier om gräsmattans historiska utveckling, flora och ekologi, liksom sociala aspekter, kommer från den angloamerikanska forskningen (Ignatieva *et al.*, 2015). Det finns ingen enkel definition på vad en gräsmatta är, vilket återspeglar att gräsmattan är komplex till sin natur och att den har stor betydelse både ekologiskt och socialt. Enligt *Oxford Companion to Gardens* (1991) kan en gräsmatta definieras så här (ungefärlig översättning från engelska): ”En gräsmatta är ett naturligt växtsamhälle vars kultivering har som syfte att bibehålla balansen mellan de olika gräsarterna” (A lawn is a plant community in the natural sense and lawn cultivation concentrates on maintaining the balance between the different species of grasses) (s. 331).

Gräsmattans konstgjorda karaktär lyfts ofta fram i definitioner, både av botanister och människor som arbetar med gräs på ett eller annat sätt. Gräsmattan betraktas som ett konstgjort, ängsliknande växtsamhälle som skapas genom sådd eller plantering av gräs (eller andra perenna stråväxter), och den används för olika ändamål: rekreation, estetisk funktion med mera (Laptev, 1983, s. 5). Även om gräsmattan mestadels ses ur en botanisk synvinkel, som ett växtsamhälle, är den viktigaste uppgiften hos gräsmattan att fylla en funktion för oss människor. Gräsmattor används för rekreation, sport och som en trevlig miljö för andra växter eller artefakter, men ofta beundras de för sin egen grönska (figur 4).

Vår definition av gräsmattan som fenomen är följande: ”Gräsmattan är ett av människor skapat växtsamhälle som består av kontinuerligt klippt gräs. Gräsmattan är skapad för att fylla olika funktioner (rekreation, sport eller estetiska syften). Gräsmattan innehåller i vissa fall spontant förekommande örter.”

Gräsmattor är i de flesta fall artificiellt skapade växtsamhällen, men i några länder finns gräsmattor som ursprungligen har varit ängar, betesmarker eller andra naturligt förekommande gräsdominerade områden.

Gräs och örter har ovan- och underjordiska delar som tillsammans bildar en grässvål*. Den består både av den övre delen av marken och de tätt sammanflätade rötterna, som ligger i symbios med faunan i jorden (figur 2). Grässvålen är ett viktigt särdrag hos en gräsmatta, en äng eller en betesmark.

En av gräsmattans utmärkande egenskaper är dess specifika konstruktionsteknik med jordförberedelser och val av fröblandningar. Skötseln av gräsmattan är också karakteristisk med gräsklippning, gödning, vattning och i vissa fall även luftning, som syftar till att hålla de valda gräsarterna vid liv. Andra utmärkande drag är att örter och mossor bekämpas som ogräs och att en kort gräshöjd och jämn grön färg eftersträvas.

När man talar om ”gräs” i fråga om gräsmattor är det växtarter från växtfamiljen gräs Poaceae och växter från växtfamiljen halvgräs Cyperaceae man menar. Halvgräs är stråväxter med gräsliknande morfologi. Både gräs och halvgräs i en gräsmatta präglas genom att gräsmattan regelbundet klipps för att hålla växterna kortklippta (figur 3).

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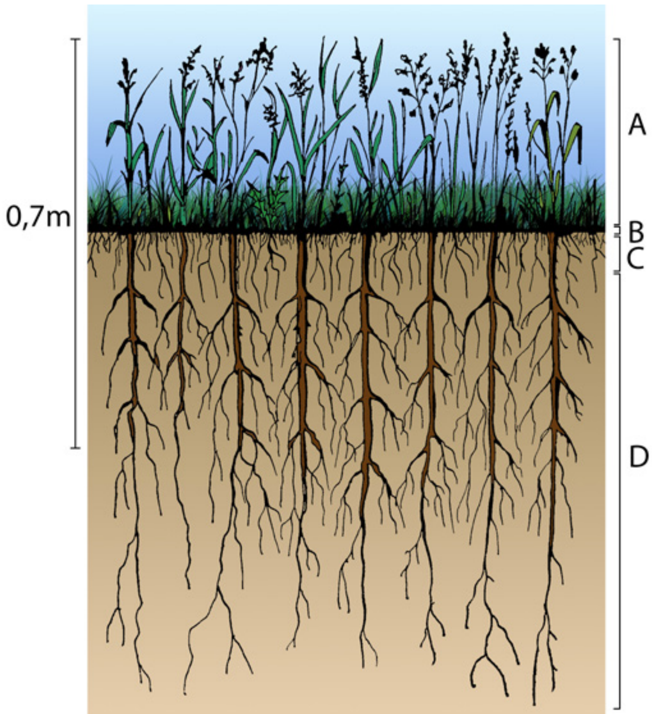
* Enligt *Nationalencyklopedin* (www.ne.se) definieras grässvål som det ”översta, rotfyllda jordlagret av gräsmark tillsammans med det (korta) gräs som växer där”. Grässvål är synonymt med grästorv, vilket enligt Nationalencyklopedin definieras som ”grästorv, i det allmänna språkbruket benämning på gräsbevuxet mullager, vilket skärs upp som ’torvor’ för att tjäna som t.ex. takbeläggning. Det byggs upp främst av minerogena partiklar och humusämnen och hålls samman av en tät filt av gräsrötter.”



Figur 2. Profilbild av grässvål:
A) gräsen och örternas strån och blad;
B) förnalagret;
C) gräsen och örternas översta lager av rötter och jord;
D) djupare liggande rötter
Anpassad från Laptev, 1983.

Figur 3. Profilbild av en typisk, regelbundet klippt, gräsmatta.
Foto: J.Lööf Green.

Biologiskt sett kan gräsmattor ses som en typ av konstgjorda ängar, och de har faktiskt vissa likheter med naturliga ängsmarker. De är växtsamhällen som består av gräs, med inslag av örter, som bildar en sammanhållande matta av grässvål. En av de viktigaste skillnaderna mellan gräsmattor och ängsliknande växtsamhällen är emellertid den högre densiteten av växtmassa. När det gäller gräsmattor växer tiotusentals skott per kvadratmeter, medan det i ängar bara växer cirka tre till sju tusen skott per kvadratmeter. Naturliga ängar har en komplicerad flerskiktsstruktur, bestående av gräs och örter i olika höjder. Gräsmattans struktur är däremot enkel och består vanligtvis av ett enda lager. En annan viktig skillnad mellan ängar och gräsmattor är gräsmattans större behov av kontinuerlig skötsel. Sålunda är huvuddragen hos de flesta typer av moderna gräsmattor lika: olika sorters gräsarter används vid etableringen, en tät grässvål skapas och sedan sker en regelbunden klippning av gräsmattan.

Det finns många hypoteser gällande gräsmattans ursprung. En teori är att gräsmattor härrör från ängar eller betesmarker (naturligt eller mänskligt skapade) i Europa. Jordbrukare skiljer på äng och hage. En äng är en gräsmark som slås för att bli hö åt boskap under vintermånaderna och kan därefter efterbetas. En hage nyttjas som betesmark åt boskapen.

Figur 4. Gräsmattans användningsområden: rekreation, sport och för att avnjuta det öppna landskapet och gräsets gröna prakt. Foto: M.Ignatieva.

KAPITEL 1

Resultat från LAWN-projektet

Målet med forskningsprojektet LAWN har varit att studera gräsmattan ur olika perspektiv: som socialt och ekologiskt fenomen, för att förstå gräsmattans roll i en hållbar stadsplanering samt hur man bäst designar och sköter gräsmattan. Ett tvärvetenskapligt tillvägagångssätt gjorde det möjligt för oss att utbyta kunskaper mellan olika discipliner och att uppnå en mångdimensionell förståelse av gräsmattan.

Genom att engagera olika intressenter i LAWN-projektet fick vi tillgång till förstahandsinformation om de fördelar en god planering innebär och vilka problem som kan dyka upp i samband med skötsel och underhåll. Våra intressenter har delat med sig av sina kunskaper, vilket har gett oss möjlighet att i denna handbok även erbjuda praktiska råd, som ett komplement till våra teoretiska rekommendationer.

LAWN-projektet finansierades av forskningsrådet Formas och drevs under åren 2013–2016. Den del av forskningen som gällde golfbanor genomfördes med hjälp av STERF (Scandinavian Turfgrass and Environmental Research Foundation).

I LAWN-projektet valdes studieområden ut inom tre svenska städer (Uppsala, Malmö och Göteborg). Undersökningar genomfördes främst i två dominerande grannskapstyper: i folkhemsområden och i miljonprogramområden. Dessa två grannskapstyper hyser båda en betydande del gräsmattor inom bostadsområdena och är de två vanligaste grannskapstyperna i svenska städer.

Vårt övergripande mål med LAWN-projektet var att erhålla tvärvetenskapliga kvantitativa och kvalitativa data om gräsmattor, för att kunna dra slutsatser om deras positiva och negativa miljöpåverkan i städerna.

VI STUDERADE GRÄSMATTOR FRÅN TRE OLIKA PERSPEKTIV:

- stor skala, hela staden inkluderas (uppskattning av gräsmattans totala täckning som markanvändningstyp);
- mellanskala, hela grannskapet inkluderas (gräsmattstypologi, förekomst av gräsmattor, gräsmattors funktioner, människors värderingar rörande gräsmattor och stadsbors användning av gräsmattor);
- liten skala, individuella gräsmattor som biotoper (biologisk mångfald och kolinlagring).

VI UNDERSÖKTE OLIKA ASPEKTER AV GRÄSMATTOR:

- generell förekomst av gräsmattor i svenska städer;
- historiska rötter, perceptioner, normer, estetiska och designmässiga värden inom nuvarande skötselmetoder för gräsmattor;
- hur de olika mänskliga intressena och värderingarna interagerar (eller konkurrerar) ur ett skötselperspektiv och hur man hittar hållbara planerings- och designlösningar;
- motiv för beslut om etablering och skötsel av gräsmattor bland olika intressenter;
- miljöpåverkan (energianvändning och klimatpåverkan);
- biologisk mångfald (växter, humlor, fjärilar och daggmaskar).

Typer av svenska gräsmattor som ingår i vår forskning

Klassificeringen av svenska gräsmattor baseras huvudsakligen på skötselmetoder (främst klippningsfrekvensen) och höjden på det klippta gräset. Svenska kommuner indelar vanligtvis gräsmattan i tre kategorier: prydnadsgräsmattan (en dekorativ gräsmatta eller paradgräsmatta som kräver mycket skötsel), bruksgräsmattan (vanligaste typen av gräsmatta – den konventionella gräsmattan som klipps många gånger under växtsäsongen) och den ängsliknande gräsmattan (som är högväxt och klipps endast en eller två gånger under växtsäsongen).

Dekorativa gräsmattor, som kräver den mest intensiva skötseln, är inte särskilt vanliga i Sverige (se tabell 1 i kapitel 3). Därför inkluderade vi i vår forskning golfbanor, med gräsmattstyper som varierade mellan allt från utslagsplatser (tee) och greener med mycket intensiv skötsel till fairways med mellanintensiv skötsel och ruff med den lägsta skötselintensiteten.

Herbicider kan användas för gräsmattor på golfbanor. På offentliga gräsmattor i svenska städer är herbicider dock ovanliga. Vi undersökte alltså gräsmattor med tre olika skötselintensiteter: golfgräsmattor, konventionella gräsmattor inom bostadsområden och ängsliknande gräsmattor (Ignatieva *et al.*, 2015). Gräsmattorna vi studerade har olika ursprung. Några av ytorna där det idag finns gräsmattor var jordbruksmark före 1950-talet, en del var skogsgläntor med berg i dagen (i Göteborg) och några mindre områden var tidigare betesmark eller skog.

Konventionella gräsmattor och de flesta ängsliknande gräsmattor (särskilt höggräskategorin, se kapitel 3) såddes med samma gräsblandningar. Det fanns dock förmodligen små mängder växter kvar som härstammade från den ursprungliga ängen eller betesmarken, särskilt i Uppsala och Göteborg (figur 5).

Figur 5. (Vänster bild) Flygfoto av ett 200 m² område i Göteborg 1960, av vad som verkar vara jordbruksmark, berg i dagen och ängar och hagar (foto: Lantmäteriet). (Mittenbilden) Vid år 2014 har dessa ersatts av bostäder och skog, med (högra bilden) gräsmattor i ljusgrön färg och skog eller buskar i mörkgrön färg (bilder: ArcMap). Grafik: M.Hedblom.

Resultat från LAWN-projektet

Gräsmattor dominerar våra urbana grönområden i Sverige. De upptar så mycket som 40-60 % av den totala ytan i urbana grönområden. Totalt täcks cirka 23 % av de svenska städerna av gräsmattor (medelvärdet av de tre storstäderna). Sett till den totala markytan i Sverige upptar de 0,6–0,9 % av Sveriges yta. Omkring 26 % av de svenska gräsmattorna har haft en aktiv skötsel i minst 50 år (Hedblom *et al.*, 2017).

Koldioxidavtryck

Vår forskning om koldioxidutsläpp visade att gräsmattor har en positiv effekt på jordens kolbalans. Den ackumulerade mängden kol i marken var högre i gräsmattorna som studerades än i ängar och närliggande jordbruksmark, eftersom produktionen av biomassa stimuleras genom frekvent klippning (Poeplau *et al.*, 2016).

Produktionen av biomassa ovan jord var också den viktigaste drivkraften för observerade skillnader i jordkollager i golfbanorna, där greenerna hade den lägsta och ruffen den högsta biomassaproduktionen, medan fairways placerade sig mitt emellan. Koldioxidlagren ökade i samma ordning (Poeplau *et al.*, 2016; Wissman *et al.*, 2016).

Sammantaget indikerade våra jordstudier att koldioxidutsläppet var högst i urbana gräsmattor och i ruffer på golfbanor, vilka är områden med en intermediär klippningsintensitet som gynnar produktion av biomassa ovan jord. Den positiva kolsekvestreringseffekten upphävs dock genom klippning, bevattning och gödsling – vilket kräver energi från fossila bränslen, leder till arbetskraftskostnader samt orsakar utsläpp av växthusgaser. Enligt våra data (Tidåker *et al.*, 2017) var klippning det som bidrog mest till ökad energianvändning för ängar, gräsmattor och ruffar (i golfbanor). Den årliga kolinlagringen var högre än utsläppen från skötseln av ängar, konventionella bruksgräsmattor och ruffar, men lägre från fairways. Emellertid sjunker kolinlagringen över tid.

Således kan gräsmattor ses som en källa till växthusgaser såväl som en förminskande faktor. Slutsatsen från vår forskning är att klippningen är den främsta orsaken till växthusgaser från de flesta gräsmattor. Minskad klippfrekvens och elektriska maskiner kan minska gräsmattornas koldioxidavtryck.

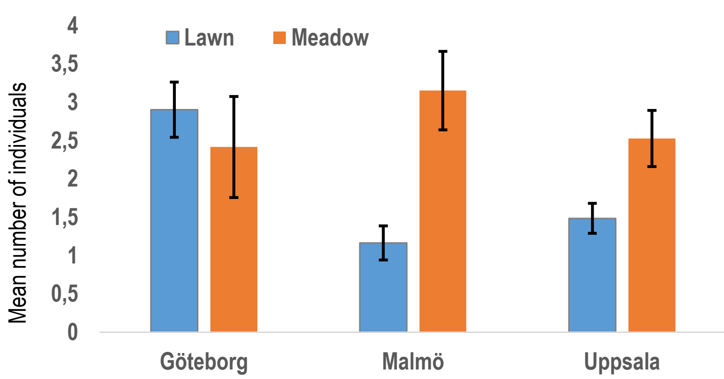
Biologisk mångfald

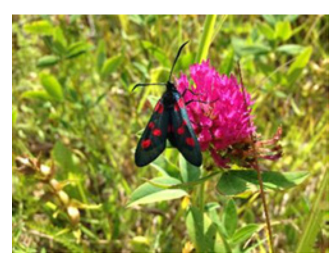
Vår ursprungliga hypotes var att den biologiska mångfalden (kärlväxter, daggmaskar och blombesökande insekter såsom humlor, honungsbin, fjärilar och bastardsvärmare) skulle vara högre i ängsliknande gräsmattor än i de konventionella. Insekterna var fler både till antalet individer och antalet arter i ängsliknande gräsmattor jämfört med konventionella gräsmattor i två av tre städer (Malmö och Uppsala). I Göteborg var det emellertid ingen skillnad på antalet individer av blombesökande insekter mellan ängsliknande och konventionella gräsmattor, och artrikedomen var faktiskt högre i konventionella än i ängslika gräsmattor i Göteborg (figur 6).

Växtarterna följde ett liknande mönster: mångfalden av växtarter (örter) var större i ängsliknande gräsmattor än i konventionella gräsmattor i Malmö och Uppsala, medan motsatsen rådde i Göteborg (figur 7). Följaktligen var det genomsnittliga antalet arter (artrikedomen) högre i ängsliknande gräsmattor i Malmö och Uppsala jämfört med konventionella gräsmattor, men ingen sådan skillnad kunde upptäckas i Göteborg (figur 8).

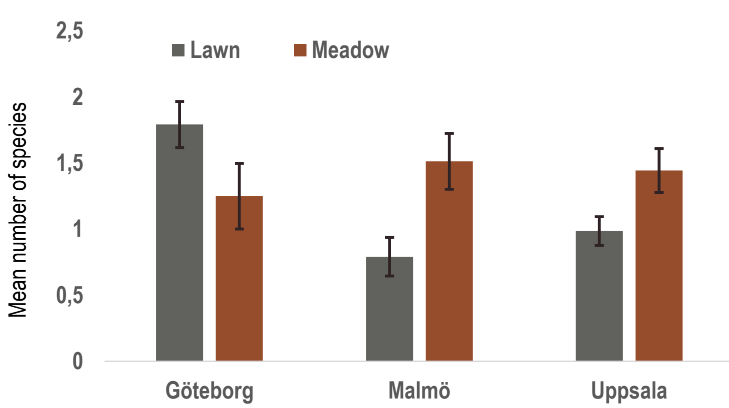
En förklaring till resultaten från Göteborg kan vara generellt låg artrikedom i båda typerna av gräsmattor, men också skillnader i tidpunkten för klippningen av ängsliknande gräsmattor. Trots att vi uteslöt ängsliknande gräsmattor som nyligen klippts, kan tiden sedan klippning ha påverkat blomningsmönstren olika beroende på t.ex. temperatur eller nederbörd. I alla tre städer var influensen av vitklöver *Trifolium repens* särskilt hög i konventionella gräsmattor, där det i många fall var den enda växten som kunde locka bin och fjärilar (figur 9). Andra arter som var vanliga lokalt och som kan locka bin och fjärilar i bruks-

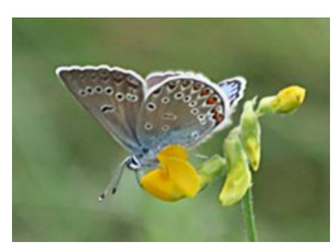
POLLINATÖRERNAS ABUNDANS OCH ARTRIKEDOM





Bredbrämad bastardsvärmare, *Zygaena lonicerae*. Foto: Pavel Bína.





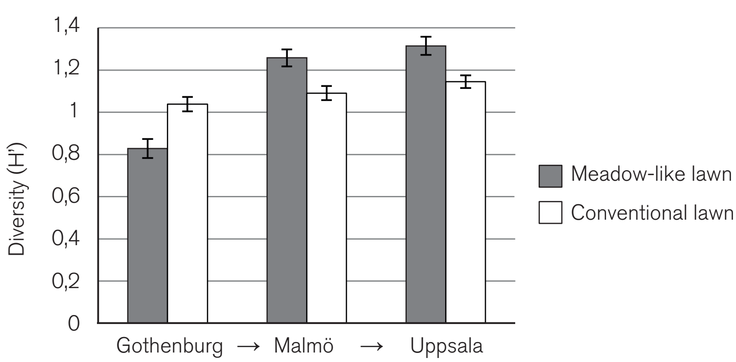
Silverblåvinge, *Polyommatus amandus.*

Figur 6. Pollinatörernas abundans (övre diagrammet) och artrikedom (nedre diagrammet) i konventionella och ängsliknande gräsmattor. Grafik: K.Ahrné.

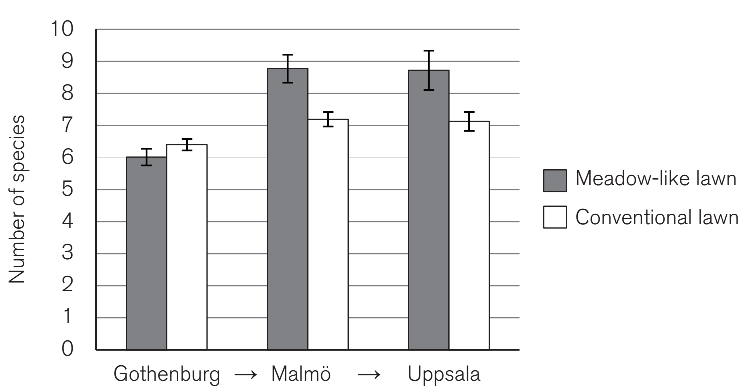
gräsmattor var brunört *Prunella vulgaris*, maskrosor *Taraxacum sp.* och humlelusern *Medicago lupulina*. Dessa växter är mycket plastiska, kan anpassa sig till ett krypande växtsätt och har möjlighet att producera blommor även vid frekvent klippning.

Kärlväxter och blombesökande insekter (humlor, honungsbin, fjärilar och bastardsvärmare) undersöktes även i fairways, ruffer och högruffer på golfbanor. Mångfalden (Shannon-Wiener-indexet) av blommande växter skilde sig mellan skötseltyperna, där ruffen hade lägre mångfald än högruff och fairway hade lägre mångfald än ruff. Antalet reproduktiva enheter (knoppar, blommor och frukter) per ruta, 0,5 m x 0,5 m, skilde sig också mellan skötseltyperna, där ruff hade ett lägre antal reproduktionsenheter än högruff, medan ingen sådan skillnad kunde hittas mellan fairway och ruff. De reproduktiva enheterna kan betraktas som både en indikation på växtens reproduktiva potential (frukt) och som insektsresurser (främst blommor och frukter).

Skötseltypen hade allmänt sett effekt på antalet blombesökande insektsarter, antalet enskilda insekter som besökte blommor och antalet blombesök. När man jämförde enskilda par av skötseltyper, var antalet blombesökande insektsarter högst i högruff, medan antalet blombesökande insektsarter var lägst i fairway. Men gällande antalet individer insekter som besökte blommor och antal blombesök hade fairway ett lägre antal enskilda blombesökande insekter medan ruff och högruff inte kunde åtskiljas. Besökande insektsindivider var beroende av antalet blommor (som lockade till sig blombesökande bin och fjärilar) i fairways, men detta förhållande mellan faktorerna var väldigt svagt i ruff och kunde inte upptäckas i högruff.



Figur 7. Genomsnittlig växtartsmångfald i 0,5 m x 0,5 m rutor i två behandlingar i tre städer: Göteborg, Malmö och Uppsala. Mångfald visas som Shannon-Weiner diversitetsindex H '. Grafik: J.Wissman.



Figur 8. Genomsnittliga antalet växtarter (örter och gräs) i 0,5 m x 0,5 m rutor i två behandlingar i tre städer: Göteborg, Malmö och Uppsala. Grafik: J.Wissman.

Figur 9. Vitklöver *Trifolium repens* är den bästa arten för att locka pollinatörer till konventionella gräsmattor. Uppsala, juli 2015. Foto: M.Ignatieva.

Daggmaskar är viktiga jordorganismer som bidrar till god jordstruktur, markluftning, vatteninfiltrationskapacitet och jordens bördighet (Lee, 1992; van Groenigen *et al.*, 2014). Vi samlade daggmaskar på 24 gräsmattor i Uppsala, fördelat på fyra områden (två folkhemsområden och två miljonprogramområden), med tre ängsgräsmattor och tre konventionella bruksgräsmattor åtskilda av minst 100 m i varje område. Daggmaskarna samplades i oktober 2014 med hjälp av allylisotiocyanat-lösning (AITC) i en koncentration av 0,1 mg ATIC/L vatten) för att extrahera maskarna från jorden, enligt Zaborski (2003).

Maskarnas artmångfald tenderade att vara högre i ängsliknande gräsmattor än i konventionella bruksgräsmattor. Detta var också fallet med abundans, medan inga skillnader i biomassa hittades mellan de två typerna av gräsmatta. Våra resultat antyder komplexa relationer mellan daggmaskar och jordvariabler som kan bero på skötselmetoder som exempelvis gödningsfrekvensen. Resultaten indikerar att urbana gräsmattor inte har särskilt ont om varken daggmaskarter eller -individer, och att grässkötseln potentiellt kan påverka daggmaskarna. Ängsliknande gräsmattor som klipps bara några gånger per år hade en högre artrikedom än de mer intensivt klippta bruksgräsmattorna.

Konventionella gräsmattor uppvisar lokalt en låg biologisk mångfald, men det är ännu viktigare att förstå att de är mer ekologiskt homogena och har en lägre beta-diversitet. Detta antyder att orsaken till homogeniteten bland konventionella gräsmattor har med mänskligt inflytande att göra. Sveriges kommuner är ansvariga för att ha anlagt gräsmattor i de flesta flerbostadshusområden. De har 50 års erfarenhet av att anlägga gräsmattor, föreslå typ av gräsmatta och framför allt av skötseln, där klippningen är det viktigaste momentet. Våra resultat beträffande homogenitet bekräftas av nya rön från USA som visar att den homogena artsammansättningen i privata gräsmattor är starkt påverkad av skötseln (Wheeler *et al.*, 2017).

Sociala studier

Resultaten av de sociala studierna visade att folks inställning till gräsmattor är positiv, även om de inte alltid använder dem aktivt. För de flesta av de tillfrågade personerna var gräsmattor önskvärda element i grönområden. Gräsmattor uppskattades särskilt som viktiga platser för olika utomhusaktiviteter (lek, vila, picknick, promenader och umgänge) eller bara för beskådande. Men vi fann också att det i vissa grannskap fanns ganska stora gräsmattor som inte användes. Sådana områden är oftast tomma, men ständigt klippta och underhållna. En av de viktigaste slutsatserna i vår sociala studie var att människor vill ha en mängd grönområden som ger utrymme för olika sinnen (ljud, lukt, beröring och syn) och inte bara en enformig gräsmatta.

Vi frågade också invånarna om möjligheterna att använda olika typer av alternativa gräsmattor (figur 10).

Figur 10. Tre alternativ till gräsmattor som presenteras med fråga 5: Vad tycker du om alternativa gräsmattor, såsom örtgräsmatta med lågväxta örter, ängar med perenner, eller måleriska ängar. Bilder: J.Vilkenas och A.Helner, 2014.

Äng med perenner *Målerisk äng* *Örtgräsmatta*

I många fall uttryckte invånarna positiva attityder till alternativa gräsmattor, men hög vegetation (ängsliknande gräsmattor eller måleriska ängar) var i de flesta fall inte önskvärt nära husen, eftersom man trodde att högt gräs bar med sig fästingar och ormar. Uppskattningsvis 20 % av de intervjuade uppgav också att högt gräs kan se ostädat ut.

Många tyckte att örtgräsmattan (blommande gräsmattor med lågt växande örter) var ”otroligt vacker”. Fleråriga ängar inramade av klippta konventionella gräsområden fick i många fall positiva svar från respondenterna (Ignatieva *et al*., 2017).

De tre studerade städerna har en hel del entreprenörer som är inblandade i byggandet och förvaltningen av grönområden, inklusive gräsmattor. Intressenter hos stadens myndigheter antog att människor ville ha kortklippta gräsmattor. I alla de tre städerna var man dock medveten om de höga kostnaderna för skötseln och därför öppen för alternativ till traditionella gräsmattor. Till exempel var årskostnaden för gräsmattor i Göteborg 2014 2,78 kr/m^2 för konventionella gräsmattor, jämfört med 1,35 kr/m^2 för ängsliknande gräsmattor. I Uppsala var motsvarande siffror 1,92 kr/m^2 jämfört med 0,85 kr/m^2.

Ansvariga för skötseln visade ofta en mycket kortsynt praktisk inställning, där buskar, träd, stenar och bänkar betraktades som ”hinder” för att klippa gräsmattor och vattenelement (t.ex. dammar) sågs som objekt som kräver mycket underhåll (rensning av löv och tillfälligt skräp). Våra undersökningar visade även att folk ville ha fler bord och stolar på gräsmattorna, men många lokala underhållsarbetare tycker inte om att se rester efter en picknick på gräsmattorna, eftersom det kan locka till sig ”oönskade” vilda djur såsom råttor, kaniner och getingar.

Eftersom gräsmattor är ett av de vanligaste elementen i öppna urbana grönområden, värderar människor gräsmattor högt och ser dem som viktiga inslag.

Vi anser att införandet av alternativa gräsmattor kräver speciella planerings- och designlösningar anpassade för varje enskilt grannskap. Det finns en stark tendens i svenska städer att se närvaro av design och omsorg i ängsliknande gräsmattor som viktigt (Eriksson *et al*., 2016).

Vår forskning visar tydligt på att sociala aspekter och estetik påverkar beslut gällande planering och hantering av olika typer av gräsmattor. Det verkar dock finnas ett behov av att utmana det nuvarande paradigmet för den ”ideala” grässtrategin och överväga mer hållbara, resursbesparande och kostnadseffektiva metoder.

KAPITEL 2

Svenska gräsmattors historia, med en förklaring av ordet ”gräsmatta”

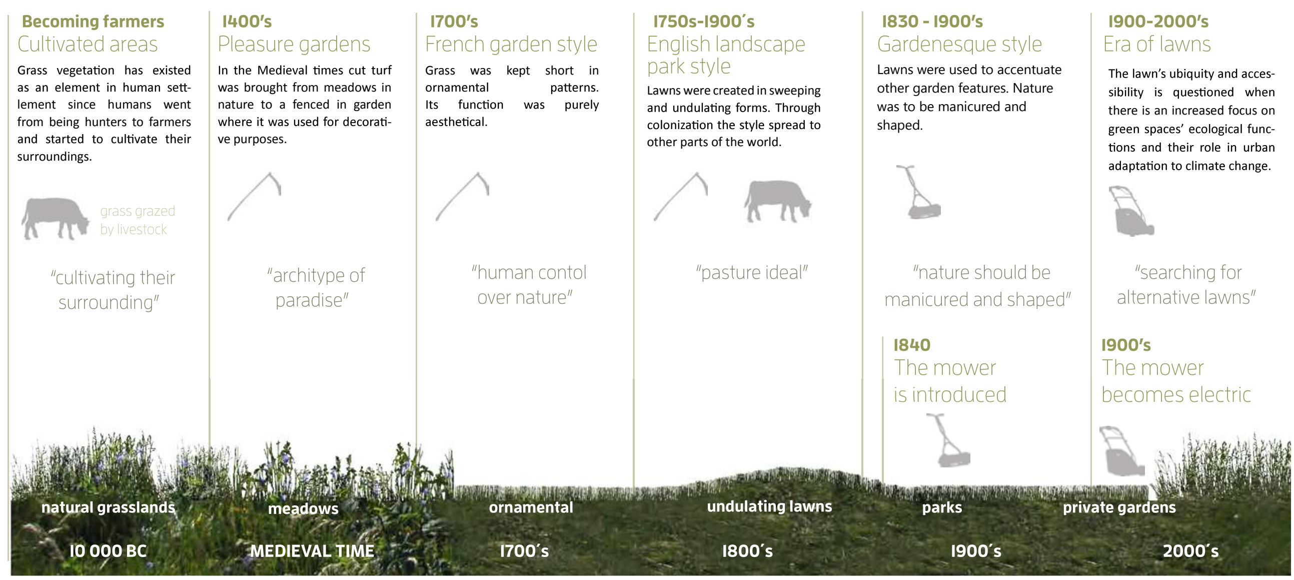
Förståelsen och definitionen av en gräsmatta har förändrats under de senaste fyra århundradena. Enligt Fort (2000) uppträdde det engelska ordet *lawn* i engelska ordböcker för första gången år 1548 och betydde då ett öppet utrymme mellan träd, vilket faktiskt ganska mycket liknar den moderna användningen av gräsmattan. Således erkändes den mycket viktiga funktionen hos gräsmattan – att fungera som en koppling mellan olika landskapselement. I Frankrike fanns ett speciellt ord, *gazon*. Lingvister tror att detta ord härstammar från det Frankiska *wason* och användes allmänt för att beteckna ”mark täckt av gräs”. Emellertid diskuterar etymologer och trädgårdshistorieforskare fortfarande ursprunget till ordet gräsmatta (Ignatieva *et al*., under granskning).

Användningen av ordledet ”gräs” i det svenska ordet gräsmatta kommer från antiken och återspeglar utvecklingen av svenskt jordbruk, där gräsbevuxna områden hade stor betydelse för uppfödningen av boskap.

Enligt en svensk historiker är lövängar den äldsta kända formen av avsiktligt odlad mark – inhägnade, betade ängar med träd (Jacobsson, 2013). Ordet trädgård syftade antagligen på en äng med fruktträd (Jakobsson, 2013). Därmed blev betade ängar ett av huvudinslagen i det svenska landskapet (figur 11). De stora skogarna spelade också en roll, eftersom skogarna ofta också användes som betesmarker. Under medeltiden användes också det latinska ordet *pratum* (äng, fält) i Sverige. Sannolikt användes ordet, i klosterträdgårdar, för grässvål hämtad från befintliga ängar eller betesmarker. Sjok av grässvål lyftes från betesmarkerna för att skapa en pratum, och dessa sjok inkluderade såväl gräs som örter.

Bilder av gräsbevuxna bänkar och sittplatser finns i många målningar från det medeltida Europa. Svenska kyrkor har också några målningar, till exempel från Antwerpen (figur 12). I den bilden kan man se den gräsbevuxna bänken där Jungfru Maria och Sankta Clara sitter. Där finns också några vildblommor i gräset.

DEVELOPMENT OF LAWNS



Figur 11. Svenska gräsmattors utveckling.
Grafik: S.Andersson och U.Bergbrant (2015).

Enligt en undersökning av brittiska forskare (Woudstra & Hitchmough, 2000) fanns det på medeltiden två typer av gräsytor: små väldefinierade gräsbevuxna områden (gräsmattor) och blomrika gräsytor, vilka skapades genom att man lade till lokala och exotiska örtplantor till befintlig grässvål.

En annan brittisk forskare, Eleanor Rohde, introducerade termen blommande äng (eng. Flowery Mead) för att beskriva blommande, artrika medeltida gräsmattor, baserat på bilder som finns tillgängliga i gobelänger och målningar. Hon föreslog att dessa blommande ängar var ”imitationer av den naturliga ängen, och liksom den naturliga ängen var de stjärnströdda med blommor” (Woudstra & Hitchmough, 2000, s. 30).

I den svenska bibelöversättningen från 1526 används det sammansatta ordet gräsplats (Ignatieva *et al.*, under granskning). Detta motsvarar observationer från brittiska författare, som hävdar att områden med likformigt klippt gräs som vi betraktar som gräsmattor ”hänvisades till som gräsplats eller gräsområden” under medeltiden och fram till 1700-talet (Woudstra & Hitchmough, 2000, s. 31).

Under 1600-talet, då franska formella trädgårdar hade sin storhetstid i Europa, överfördes den franska terminologin kring gräsmattor som

Figur 12. (Vänster) "Jungfrun sittande på en låg mur plockandes en blomma för Kristusbarnet, Sankta Agnes, Sankta Dorothea och ett annat kvinnligt helgon (möjligen Sankta Barbara) i en sluten trädgård bortom, ett omfattande flodlandskap med en stad i bakgrunden" av mästaren i Tiburtine Sibyl, 1468. Källa: www.artvalue.com/auctionresult--master-of-the-tiburtine-sibyl-the-virgin- seated-on-a-low-wal-1750594.htm. (Höger) Sankta Clara och Jungfru Maria. 1500-talet. Altartavla. Antwerpen workshop (Historiska muséet i Stockholm). Foto: M.Ignatieva.

dekorativa kortklippta gräsdominerade ytor (*parterre de gazon* och *tapis vert*) till svenska. Förmodligen såg svenska läsare ordet gazon för första gången i Le Jardin de Plaisir av André Mollet, som publicerades på svenska år 1651 (Mollet, 1651). Gazoner etablerades endast i kungliga och adliga trädgårdar och användes i parterrer och vid gränser av parterrer där figurklippta träd och blommande växter visades. Gazoner var mycket tidskrävande och pengakrävande inslag. De krävde speciella fröblandningar (eller grässvål av god kvalitet från betesmarker), speciella anläggningstekniker och intensiv skötsel (figur 13).

De flesta författare hävdar att gräsmattan verkligen fick sitt eget liv i mitten av 1700-talet, som en ganska stor yta med en skötsel som syftade till att hålla gräset kort, och blev det viktigaste inslaget i trädgårdarna då det kunde täcka ganska omfattande områden (Dawson, 1959; Schultz, 1999; Jenkins, 1999). Rekommendationen vid den tiden var att samla gräset från högt belägna betesmarker av god kvalitet (Dawson, 1959). Med utvecklingen av plantskolor och med dem produktionen av gräsfröblandningar, under andra hälften av 1700-talet, blev det lättare att skapa lena, gröna gräsmattor med fint kortklippt eller kort betat gräs.

Figur 13. Parterre med gräsmatta (gazon) som det dominerande elementet. Drottningholms Park, Stockholm. Foto: M.Ignatieva.

Figur 14. Hagaparkens pelouse är Sveriges mest kända. April 2014. Foto: M.Ignatieva.

Figur 15. Folkhemsområde i Tunabackar, Uppsala. Juni 2013. Foto: M.Ignatievaa

Användningen av det franska ordet *pelouse* (ett annat ord för gräsmatta, Mosser, 2000) är direkt relaterat till utvecklingen av landskapsparker i Sverige i slutet av 1700-talet (figur 14).

Ordet gräsmatta återfinns i svenska ordböcker först år 1852 i den nuvarande betydelsen av en grön gräsmatta eller ett ”mattliknande täcke av (fint och ogenomträngligt) gräs som täcker marken” (Lundström, 1852, i SAOB; Ignatieva *et al.*, under granskning). Uppkomsten av det svenska ordet gräsmatta är direkt knuten till spridningen av offentliga parker i Sverige och en stor användning av gräsmattor som ett viktigt dekorativt inslag. Det svenska ordet gräsmatta delar också 1900-talets engelska betydelse av lawn som en grön matta som avsedd att användas.

Den stora spridningen av gräsmattor följde med den funktionalistiska rörelsen (den svenska modellen) implementerad av det Socialdemokratiska partiet mellan 1930- och 1970-talet. Ett mål för den svenska socialdemokratiska ideologin var att skapa en progressiv välfärdsstat, som bland annat skulle tillhandahålla bostadsområden med sunda utomhusmiljöer för arbetarklassen. Som en följd av den funktionalistiska rörelsen byggdes under 1930- till 1950-talet områden med flerfamiljshus som kallades Folkhemsbebyggelse. Senare genomfördes det som kallades Miljonprogrammet, mellan mitten av 1960-talet och mitten av 1970-talet. Gräsmattor var det dominerande inslaget i utomhusmiljön (för lek, promenad och vila) i båda dessa typer av bostadsområden (figur 15).

Gräsmattor som standardiserade inslag passar perfekt med den modernistiska estetikens prefabricerade rationalistiska landskapselement och begränsade variation i designen (Ignatieva *et al.*, 2017).

Gräsmattor spelar också en viktig roll i den privata trädgårdsutformningen i svenska städer. Moderna stadsdelar använder fortfarande gräsmattan som ett viktigt designelement i utomhusmiljön (figur 16).

Figur 16. Gräsmatta i en villaträdgård i Bräcke, Göteborg. Juni 2014. Foto: M.Ignatieva.

KAPITEL 3

Typer av gräsmattor och gräsdominerade områden i svenska kommuner

De svenska nationella riktlinjerna för gräsmatteskötsel delar in gräsytor i fyra typer: prydnadsgräsmatta, konventionell gräsmatta, högt gräs och äng. Huvudskillnaderna mellan dessa typer är gräshöjd och klippningsintensitet (figur 17). Ängsliknande områden klipps en eller två gånger per år. Högt gräs kräver klippning 2–5 gånger per säsong, medan konventionella gräsmattor kräver frekventare klippning, 12–20 gånger per säsong (beroende på väderförhållandena). Prydnadsgräsmattan ska klippas 18 till 25 gånger per säsong och kräver det kortaste gräset, 2,5–6 cm. Funktionerna för de olika typerna skiljer sig också åt. Prydnadsgräsmattan skall främst ha ett högt estetiskt värde, som ett viktigt dekorativt rumsligt element, medan den konventionella gräsmattan används för rekreation och sport.

Figur 17. De olika typerna av gräsmattor i Sverige (Andrén, 2008; Andersson & Bergbrant, 2015).

År 2001 utgjorde konventionella gräsmattor cirka 55 % av gräsytorna i svenska städer. Det följdes av ängsliknande gräsmattor (högt gräs 30 %, äng 11 %) och prydnadsgräs (4 %) (Svenska Kommunförbundet, 2002).

Denna klassificering innehåller, i varje stad, variationer (underkategorier) inom de konventionella kategorierna bruksgräsmattor och ängsliknande gräsmattor. Dessa är baserade på antalet klippningar och, för konventionella gräsmattor, även gräsens höjd (tabell 1). Som uppgifterna i tabell 1 tydligt visar, är högt gräs i moderna städer ett ganska vanligt alternativ till konventionella gräsmattor och ingår i den större kategorin av ängsliknande gräsmattor.

Prydnadsgräsmatta finns fortfarande i Malmö och Göteborg (i dessa städer kallas den även ”paradgräsmatta”), men har nästan helt försvunnit i Uppsala.

TABELL 1. TYPOLOGI FÖR GRÄSMATTOR I UPPSALA, GÖTEBORG OCH MALMÖ (BASERAD PÅ KOMMUNALA DATA FRÅN 2015). HÄR ANVÄNDS DE URSPRUNGLIGA FÖRKORTNINGARNA FÖR OLIKA TYPER AV GRÄSMATTOR I DE TRE STÄDERNA.

STAD	KONVENTIONELL GRÄSMATTA	ÄNGSLIK GRÄSMATTA
Uppsala	G1: Klipps regelbundet och gödning tillsätts G2: Klipps regelbundet för att uppnå en maxhöjd på 8–10 cm	G3: Klipps två gånger per år G4: Klipps en gång per år
Göteborg	A: Paradgräsmatta; klipps och vattnas kontinuerligt C: Bruksgräsmatta som klipps kontinuerligt. För lek sport eller annan aktivitet D: Klipps kontinuerligt	Slåtteryta A med upptag: Anlagd eller naturvuxen ängsyta som slås tre gånger per år med upptag varje gång. Slåtteryta B med upptag: Anlagd eller naturvuxen ängsyta som slås två gånger per år med ett upptag. Slåtteryta C med upptag: Anlagd eller naturvuxen ängsyta som slås en gång per år med upptag. Slåtteryta A: Anlagd eller naturvuxen slåtteryta som slås tre gånger per år Slåtteryta B: Anlagd eller naturvuxen slåtteryta som slås två gånger per år Slåtteryta C: Anlagd eller naturvuxen slåtteryta som slås en gång per år.
Malmö	G1: Paradgräsmatta G2: Aktivitetsgräsmatta	G0 – Friväxande gräs G4 – Högt gräs med uppsamling 1 gång/år G6 – Högt gräs klippning 2 ggr/år G7 – Högt gräs klippning 4 ggr/år G10 – Högt gräs med manuell uppsamling G11 – Ruderatmark

Paradgräsmattor är den mest intensivt skötta kategorin gräsmattor i Sverige. De klipps och vattnas kontinuerligt under hela säsongen. Denna typ av gräsmatta används som ett speciellt dekorativt element, en grön fond för att visa växter, arkitektur eller skulptur. För paradgräsmattor rekommenderas fina gräs som rödsvingel *Festuca rubra*, ängsgröe *Poa pratensis*, rödven *Agrostis capillaris* och engelskt rajgräs *Lolium perenne*. Alla andra arter, som alltså inte är avsedda att finnas med i den ursprungliga fröblandningen, är inte välkomna i paradgräsmattan, eftersom de kan förstöra den gröna mattans mjuka och jämna utseende (figur 18).

Figur 18. Exempel på paradgräsmatta. Botaniska trädgården i Uppsala, oktober 2013. Foto: M.Ignatieva.

Konventionella gräsmattor

Konventionella gräsmattor (figur 19) är utformade för att vara hållbara och kunna klara olika fritidsaktiviteter. Således kallas dessa gräsmattor ”bruksgräsmatta” eller ”aktivitetsgräsmatta” i ovanstående klassificering. De etablerade klippningsrutinerna gör denna kategori mycket vanlig i städerna. Den önskade gräshöjden är ca 4–10 cm. Fröblandningar för sådana gräsmattor består av en kombination av gräsarter. I Sverige är rödsvingel *Festuca rubra*, rödven *Agrostis capillaris*, engelskt rajgräs *Lolium perenne*, timotej *Phleum pratense* och ängsgröe *Poa pratensis* de vanligaste grässorterna i konventionella gräsmattor.

Våra resultat från LAWN-projektet beträffande biologisk mångfald bekräftar att *Festuca rubra* är det vanligaste gräset i Sverige. Denna art är torktolerant och klarar av att klippas riktigt bra. Allt eftersom tiden går blir den ursprungliga gräsmattan, som är baserad på gräsarter, berikad med örter från fröbanken i omgivande växtsamhällen. Närvaron av sådana örter är mycket fördelaktig för den biologiska mångfalden hos konventionella gräsmattor. Våra studier i LAWN-projektet av konventionella gräsmattor visade stor abundans av vitklöver *Trifolium repens*, röllika *Achillea millefolium*, majsmörblomma *Ranunculus auricomus* och revfingerört *Potentilla reptans*.

Den konventionella gräsmattans huvudsakliga skötsel består av frekvent gräsklippning. Allmänna gräsmattor i Sverige vattnas och gödslas ej och gräsklippet samlas ej upp.

Forskare som arbetar med urbana gräsmattor (Müller, 1990; Thompson *et al.*, 2004; Stewart *et al.*, 2009) har visat att efter att gräsmattan har anlagts kan klimatförhållandena, användningsintensiteten och skötseln påverka växtkompositionen. Müller (1990) fann att den viktigaste faktorn är klippningsfrekvensen. Klippningsfrekvensen gynnar främst klipptoleranta arter med ett lågt växtsätt.

Figur 19. Exempel på konventionell gräsmatta i Augustenborg, Malmö. Augusti 2015. Foto: M.Ignatieva.

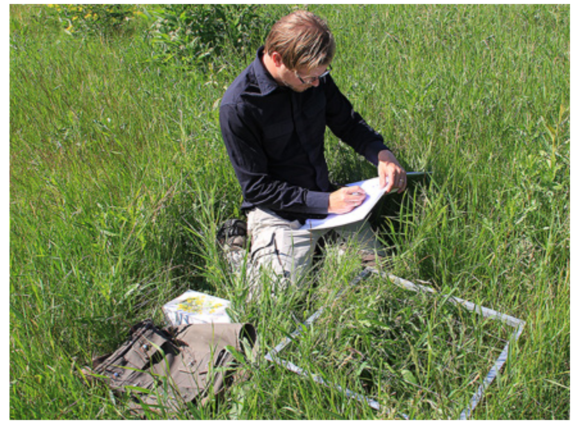
Ängslika gräsmattor (högt gräs och ängar)

Utifrån tabell 1 står det klart att den ängsliknande kategorin i verkligheten domineras av höggrässamhällen. Ängar täcker endast små områden i var och en av de tre städerna som studerats. Malmö och Göteborg har etablerat ganska detaljerade underkategorier inom den ängsliknande typen.

HÖGGRÄSGRÄSMATTOR

Höggräsgräsmattor klipps bara några gånger om året och gräset får växa högt. Dessa gräsytor ligger ofta i perifera områden och är inte avsedda för intensiv användning (rekreation och sport). Artsammansättningen i gräsmattor med högt gräs varierar, men gräs dominerar i de flesta fall. Den vanligaste arten i svenska höga gräs är timotej *Phleum pratense*, rödsvingel *Festuca rubra*, rödven *Agrostis capillaris*, ängsgröe *Poa pratensis* och hundäxing *Dactylis glomerata*. Bland örterna är de vanligast förekommande arterna rödklöver *Trifolium pratense* och vitklöver *Trifolium repens*, svartkämpar *Plantago lansolat,* käringtand *Lotus corniculatus*, humlelusern *Medicago lupulina*, röllika *Achillea millefolium* och hundkäx *Anthriscus sylvestris* (figur 20). Höga gräsytor har i allmänhet större potential för biologisk mångfald jämfört med konventionella gräsmattor, eftersom de vanligtvis tillåter örter att blomma och sprida sig (Wissman *et al.*, 2015; för resultat från LAWN-projektet, se kapitel 1 i denna handbok).

Det är möjligt att omvandla höggräsgräsmattor i en stadsmiljö till blomsterrika ängar, men det tar några år. Det kräver insamling efter klippning (för att minska jordens bördighet). Således har bara några få städer och kommuner gjort detta i större skala. Klippningsfrekvensen för högt gräs beror på områdets särdrag, vädermönster och hur högt man vill att gräset ska vara.



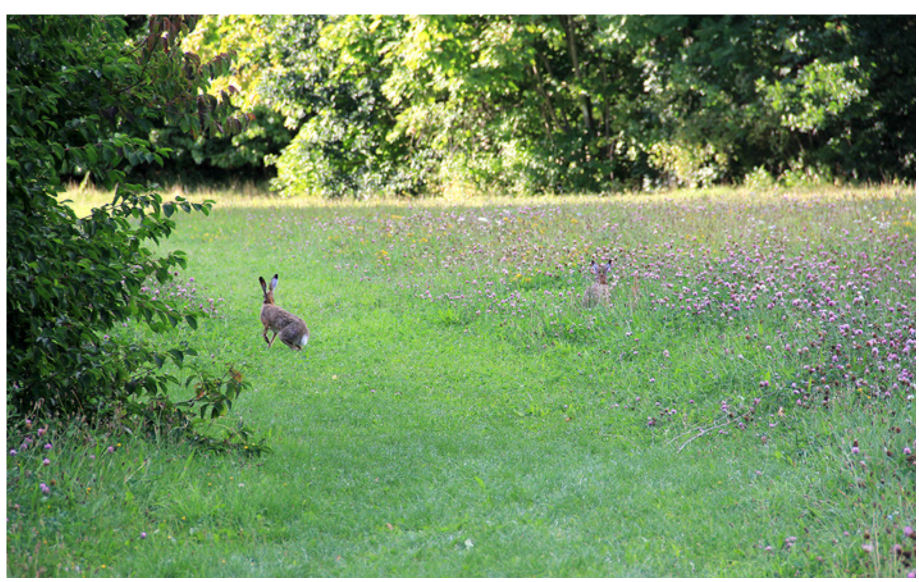
Figur 20. Ett exempel på ett höggräsområde i Uppsala. Juni 2013. Foto: M.ignatieva.

”Äkta” ängar

Numera är äkta ängsliknande samhällen med ett högt innehåll av blommande fleråriga växter sällsynta i urbana miljöer. Sådana ängar klipps vanligen en gång om året. Sammansättningen och strukturen hos ängar kan skilja sig åt och beror på tillgången på näringsämnen i marken, tillgången till vatten samt skötselmetod. I urbana grönområden är näringsrika jordar vanligast, eftersom det huvudsakliga målet är många konventionella gräsmattor. Således kan en omvandling av höggräsområde till äng ta flera år (5–10) av konsekvent skötsel (Jacobsson, 1992).

Vår forskning i LAWN-projektet visade att i ängsliknande gräsmattor spelar arter som rödklöver *Trifolium pratense*, vitklöver *Trifolium repens*, stormåra *Galium mollugo*, röllika *Achillea millefolium*, svartkämpar *Plantago lanceolata* och humlelusern *Medicago lupulina* en ganska viktig roll (figur 21). Enligt vår forskning har ängs-

Figur 21. Exempel på ängslik gräsmatta i Holma, Malmö. Augusti 2014. Rödklöver *Trifolium pratense* är den mest synligt blommande växten vid denna tid på säsongen. Foto: M.Ignatieva.



liknande gräsmattor även örtarter som vanligtvis är sällsynta gäster i stadsmiljöer. Sådana växter är viktiga eftersom de skapar biologisk mångfald. Fleråriga blommande växter ger också en naturliknande känsla i stadsmiljöer (figur 22 och 23).

Ett fullskaligt projekt kring ekologisk skötsel och underhåll genomfördes i Bulltoftaparken i Malmö 2007–2010. Där försökte man testa olika former av ekologisk skötsel, till exempel användning av en cylinderklippare som dras av hästar och bete i vissa områden, som syftar till att minska utsläppen av växthusgaser. Konventionella gräsmattor förvandlades till höga gräsytor som klipps endast en gång om året. Projektet visade att underhållskostnaden för höggräsgräsmattor var mindre än för konventionella gräsmattor (0,88 kr/m² jämfört med 0,99 kr/m²) (Johansson *et al.*, 2011).

Sammanfattningsvis kan vi i fråga om olika skötselmetoder för gräsmattor i de tre svenska städer som studerats, dra slutsatsen att den konventionella gräsmattan idag är dominerande men att det finns en ökad medvetenhet hos berörda myndighetspersoner om vikten av att införa en miljövänligare skötsel och behovet av att minska kostnaderna för gräsmattans skötsel.

I de följande kapitlen diskuteras olika typologier av alternativa gräsmattor och deras lämplighet

Figur 22. Ängsliknande gräsmatta vid skogsbrynet i ett grannskap i Uppsala. I juni skapar blommande hundkäx *Anthriscus sylvestris* en vit bakgrund. Uppsala, 2013. Foto: M.Ignatieva.

i svenska stadsmiljöer. Men dessa typer av alternativ kan inte och behöver inte helt ersätta konventionella gräsmattor. Genom att föreslå alternativ vill vi öka medvetenheten i planeringen och utformningen av gröna ytor och om införandet av ett nytt paradigm som syftar till att skapa en mångsidig och hållbar stadsmiljö och inte bara monotont, regelbundet klippta gräsmattor.

Kunskap om gräsmattans biologiska mångfald och skötselns betydelse kan hjälpa städer att göra förändringar genast, utan någon dramatisk omgestaltning eller etablering av nya typer av gräsmattor. Exempelvis kan mindre frekvent klippning, som bör utföras efter blomning av arter som vitklöver *Trifolium repens*, humlelusern *Medicago lupulina* och brunört *Prunella vulgaris*, få pollinatörer och fröätande insekter att trivas (Wissman *et al.*, 2015). Mindre frekvent klippning minskar även energiförbrukningen.

Under det senaste årtiondet har bete diskuterats som en alternativ skötselmetod för vissa urbana gräsytor i Sverige (Hellner & Vilkénas, 2014; Andersson & Bergbrant, 2015). Det finns emellertid fortfarande många aspekter att ta i beaktande innan man inför en sådan lösning i stadsområden.

Figur 23. Ängsliknande gräsmatta i utkanten av stadsdelen Eriksbo, i Göteborg. Juni 2014. Foto: M.Ignatieva.

KAPITEL 4

Typer av alternativa gräsmattor. Befintliga metoder från Europa, USA och Sverige

Det finns en ökad medvetenhet, speciellt bland de angloamerikanska och tyska forskare som studerat gräsmattor (då främst privata sådana), om ”ett enormt grupptryck att ha en fin gräsmatta” (Jenkins, 1994, s. 5). En ”fin gräsmatta” betyder ofta en yta som domineras av en gräsart (en monokultur) och där man inte tillåter andra arter utan ständigt rensar bort sådana för att få en kort och snygg grässtubb – den perfekta gräsmattan (Jenkins, 1994).

Under 1900-talet gjordes några försök att skapa alternativa gräsmattor och att berika gräsmattor med vilda blommor. I Storbritannien experimenterade till exempel William Robinson i sin vilda trädgård med härdiga inhemska och exotiska lökar och några örtartade perenner. Hermann Jäger från Tyskland föreslog användning av naturliga blommor från skogar och ängar, medan Willy Lange fick sin inspiration från naturen och presenterade en lång rad valmöjligheter och en alternativ vision för gräsmattor med fröblandningar för blommande ängar som inte bara omfattade inhemska utan också några exotiska perenner.

Sedan slutet av 1900-talet har man utforskat alternativ till den traditionella gröna gräsmattans estetik och mer miljövänliga och resursbesparande lösningar (Bormann *et al.*, 2001; Dunnett och Hitchmough, 2004; Smith, 2014). Intressant nog blev den medeltida tillämpningen av ”blomsteräng”, där gräset var fullt av vackra blommande örter, en inspiration för ”Ecolawn” med dess låga skötselintensitet, skapad av Tom Cook vid Oregon State University i USA (Schultz, 1999). Likaså för ”örtgräsmattor” eller ”gobelänger” av Lionel Smith i Storbritannien (Smith, 2014). Även Sheffield Planting Design School (Nigel Dunnett & James Hitchmough) arbetar med experimentella naturalistiska planteringar utifrån modern ekologisk kunskap (Woodstra & Hitchmough, 2000).

Befintliga europeiska hållbara alternativ till konventionella gräsmattor

ENGELSKA ANNUELLA MÅLERISKA ÄNGAR

Måleriska ängar består av inhemska och exotiska annuella växter som kornvallmo *Papaver rhoeas*, blåklint *Centaurea cyanus*, klätt *Agrostemma githago*, åkerkulla *Anthemis arvensis*, gullkrage *Chrysanthemum segetum*, sömntuta *Eschscholzia californica*, berglin *Linum perenne*, lin *Linum usitatissimum*, tigeröga *Coreopsis tinctoria*, ringblomma *Calendula officinalis* och några andra arter. Sådana ängar rekommenderas för att skapa färgglada blommande platser som också är mycket attraktiva för vilda djur. Det finns några exempel på ängar i Storbritannien (Lickorish *et al.*, 1997; Steel, 2013; Hitchmough och Dunnett, 2004). Dessa speciella ängar kräver minimalt underhåll, förutom viss ogräsbekämpning.

I Storbritannien blommar måleriska ängar från sen vår till tidig höst. Vid slutet av säsongen klipps all vegetation och tas bort. Enligt engelska forskare (www.pictorialmeadowsonline.co.uk), kan man, på grund av det milda engelska klimatet, så fröblandningar redan i mars, april och maj. Efter bara åtta veckor kan de bjuda på en färgstark uppvisning. Engelska trädgårdsodlare tror att sådana annuella ängar kan skapas på alla typer av mark. De föreslår 2,5–3 g frön per kvadratmeter. Fördelen med annuella fleråriga ängar är deras höga estetiska värde under blomningssäsongen och deras attraktion för vilda djur (figurerna 24–26). Nackdelen är att man behöver återskapa platsen varje år och i många fall använda ogräsmedel.

Figur 24. Målerisk äng som domineras av vallmo. Sheffield, Storbritannien i juni 2007. Foto: M.Ignatieva.

Figur 25. Målerisk äng vid Olympic Park, London, i slutet av maj 2014. Foto: M.Ignatieva.

Figur 26. Målerisk äng med sömntuta *Eschscholzia californica* vid Olympic Park, London, i slutet av maj 2014. Foto: M.Ignatieva.

Figur 27. Ett kantområde i Olympic Park, London, sent i maj 2014. Prästkragarna *Leucanthemum vulgare* är i full blom. Foto: M.Ignatieva.

Inhemsk äng, mix av perenner

En mix med inhemska perenna arter föreslås för att skapa mer traditionella ängar i Storbritannien. Sådana blandningar rekommenderas i England för ”creative conservation” (kreativt bevarande), det vill säga för att skapa nya platser för vilda djur i stadsmiljöer (Lickorish *et al.*, 1997) (figur 27). Många industriområden och ruderatmarker har omvandlats till viktiga naturområden. Inhemska ängar används också i vissa nya stadsdelar och rekommenderas även för privata trädgårdar. Urvalet av arter för sådana ängar är mycket beroende av jordtyp och lokala förhållanden. De mest populära arterna är prästkrage *Leucanthemum vulgare*, gulmåra *Galium verum*, blåklint *Centaurea scabiosa*, svartklint *Centaurea nigra*, äkta johannesört *Hypericum perforatum*, åkervädd *Knautia arvensis*, röllika *Achillea millefolium*, gökblomster L*ychnis floscuculi*, brudbröd *Filipendula vulgaris* och gullviva *Primula veris*. Sådana blandningar innehåller vanligtvis 20 % vildblommor och 80 % gräs och sås med 4–5 g/m². Skötseln av ängarna är ganska enkel; man klipper dem en gång om året.

Figur 28. Naturalistiska örtplanteringar med prärieväxter i Oxfords botaniska trädgårdar, i Storbritannien. Juli 2013. Foto: M.Ignatieva.

Engelska naturalistiska örtplanteringar

Naturalistiska örtplanteringar är ängsliknande växtsamhällen som består av perenna gräs och örter, inhemska såväl som några exotiska. Det finns ett särskilt intresse för dessa områden på Sheffields landskapsarkitekturskola, där man menar att människor lockas mer till färgglada örtartade växter än till blygsammare inhemska arter (Hitchmough och Dunnett, 2004). Fleråriga växter från den nordamerikanska prärien, som Rudbeckia, som växer väldigt bra i det engelska klimatet, och andra vackra perenner ”utnyttjar visuella och funktionella egenskaper” som saknas i engelska inhemska floror och ökar därmed sin attraktionskraft för människor (figur 28). En annan fördel med att använda sådana planteringar är att man ökar den biologiska mångfalden och minskar resursanvändningen; skötselintensiteten är med andra ord låg.

Huvudfokuset vid Sheffieldskolan ligger på utvecklandet av olika mixer av inhemska-exotiska ängar. Som grund använder man inhemska gräs och olika örtartade växter men tillsätter planterade exotiska örter från Himalaya/Ostasien, Kaukasus eller USA) (Kingsbury 2004; Hitchmough 2004; 2009).

Det mest kända exemplet som den naturalistiska plantskolan i Sheffield åstadkommit är det planteringskoncept man skapade för Londons Queen Elizabeth Olympic Park. Många måleriska ängar och naturalistiska örtplanteringar realiserades på denna enorma yta på 25 hektar (figur 29).

Figur 29. Naturalistiska örtplanteringar i Londons Queen Elizabeth Olympic Park. Juli 2013. Foto: M.Ignatieva.

Figur 30. Experimentella örtgräsmattor upprättades av Lionel Smith på University of Readings område. Juli 2013. Foto: M.Ignatieva.

"Grass-free/tapestry lawn" (örtgräsmatta/gobeläng)

Örtgräsmatta är den allra senaste alternativa gräsmattan som utvecklats i Storbritannien. Lionel Smith vid University of Reading föreslår att man skapar fleråriga gräsfria växtsamhällen som bara klipps några gånger per år. Han tror att sådana örtgräsmattor kan vara goda ersättare för traditionella gräsmattor, eftersom de är miljövänliga (mindre energiinsats i underhåll och ett biologiskt mångsidigt växtsamhälle), samtidigt som de är väldigt vackra att se på (Smith and Fellowes, 2014) (figur 30). Örtgräsmattorna är inspirerade av den medeltida idén om blomrika gräsmarker och ängar, som var vanliga i Storbritannien.

Figur 31. Parkeringsplats vid Universitetet för tillämpad vetenskap i Erfurt, Tyskland. Juli 2013. Foto: M.Ignatieva.

Figur 32. "Go spontaneous"-design i Park am Gleisdreieck (etablerad 2013). Bilden tagen i September 2016. Foto: M.Ignatieva.

Tyskland ”Go spontaneous”

Baserat på lång erfarenhet av forskning om stadsekologi och spontan flora efter andra världskriget, utvecklades i Tyskland designkonceptet ”Go spontaneous” med spontan vegetation. Spontan betyder här ruderat vegetation som förekommer på platsen utan någon form av mänsklig avsikt. Detta tillvägagångssätt bygger på kunskaper om växters och vegetationssamhällens naturliga etablering och succession, och syftar till att ”göra spontan vegetation mer attraktiv” (Kuhn, 2006). Tillvägagångssättet används för att omstrukturera ödemarker, övergivna industriområden och byggarbetsplatser. En mycket viktig del av detta tillvägagångssätt är att öka den biologiska mångfalden genom att använda inhemska och en kombination av inhemska och icke-inhemska arter (figurerna 31, 32).

Nordamerikanska ”prairie gardens” (prärieträdgårdar)

I Mellanvästern, USA har man lång erfarenhet av återintroduktion av inhemska prärieväxter i olika urbana livsmiljöer. Under 1900-talet introducerade Ossian Cole Simonds och Jen Jensen präriestilen i den amerikanska landskapsarkitekturen, genom sitt banbrytande designarbete. Ett av de bästa exemplen på denna präriestil kan tydligt ses i utformningen av Millennium Park i Chicago, som grundades i början av år 2000. En av parkens planteringsteman var återupprättandet av Chicagos ursprungliga växtsamhällen. Växtmaterialet i denna park domineras av inhemska präriearter, även om de förstärks av några icke-inhemska perenner (figur 33).

Figur 33. Millennium Park i Chicago, med användning av prärieväxter. Foto: CNT/Flickr (CC BY-SA 2.0).

”Cues to care” (tecken på omsorg) i USA och Storbritannien

Tecken på omsorg, eller ”Cues to care” som det heter på engelska, är ett koncept som introducerades och främjades i slutet av 1990-talet av Joan Nassauer i USA. Nassauer (1995) påpekade att det finns en motsättning mellan människors förväntningar på att stadsmiljöer ska vara snygga och välordnade och naturens ”röriga” utseende. Således kan någon av de nya föreslagna ekologiska planteringarna se stökiga och försummade ut. Det är därför det är viktigt att använda speciella designverktyg som t.ex. att rama in ängen med kanter av klippt gräs. På så sätt visas den mänskliga närvaron. Utan synlig omsorg om området kommer folk troligen aldrig att acceptera någon av de alternativa ”röriga” högväxande ängarna i städerna (figur 34).

Figur 34. "Cues to care" I ett av Londons nya stadsdelar. Utformad med tydliga kanter till den ängsliknande planteringen ger den tecken på omsorg. I slutet av maj 2015. Foto: M.Ignatieva.

Sverige

ALTERNATIVA GRÄSMATTOR SOM ETT KOMPLEMENT TILL BEFINTLIGA GRÄSMATTOR

Begreppet gräsmatta importerades till Sverige från andra europeiska länder. Men under 1800- och 1900-talet försökte man införa en tillämpning av svenskt bruk i utvecklingen av gräsmattor. En av traditionerna var att inkludera delar av det inhemska landskapet och bevara det i parker och andra gröna områden. Detta innebar att man bevarade naturlig eller halvnaturlig vegetation som skogar, ängar och betesmarker (Florgård, 2009).

Inhemska ängar användes också på 1930-talet och 1940-talet i arbetet vid Stockholmsskolan, som arbetade med utveckling av parkområden. Denna skola verkade inom områdena landskapsarkitektur och stadsplanering och förespråkade en ny vision för parkområden, som stod i motsats till de moderna, regelbundna och välproportionerade idealen där gräsmattan var ett väsentligt inslag (Florgård, 1988). Inhemska arter och vildblomsängar användes som ett komplement till konventionella gräsmattor. Ett av de bästa exemplen på en sådan park är Norr Mälarstrand i Stockholm (Sandström, 2004).

Under det sena 1980-talet och det tidiga 1990-talet genomförde forskare från SLU en serie experiment med metoder för att etablera artrika gräsmarkers vegetationsytor i byggd miljö i Alnarp och Torslunda (Hammer och Kustvall, 1991). De studerade hur plantskoleväxter och organisk komposttäckning påverkade tillväxten hos 38 örter och 8 gräs (Mårtensson, 2017).

Sverige har trädgårds- och landskapsarkitekturförbindelser med europeiska länder, särskilt Storbritannien. Det är inte förvånande att engelska naturalistiska planteringar, speciellt måleriska ängar, mottas väl i svenska städer. Idag finns det dock i Sverige ett behov av att finna alternativ till gräsmattor, som ett svar på den moderna miljökrisen, homogeniseringen av stadsmiljöerna och sökandet efter vår egen identitet liksom för att hejda klimatförändringarna (Ignatieva *et al*, 2015).

Det svenska sättet att leta efter alternativa gräsmattelösningar är inspirerat av landets rika trädgårds- och odlingshistoria. Sverige går mot en prioritering av modeller med inspiration från naturliga gräsmarksekosystem och historiska trädgårdar där ängar spelade en betydande roll. Därmed är det viktigt att använda mestadels inhemskt växtmaterial i de alternativa gräsmattorna.

PRATENSIS AB

År 2005 startade Inger och Mats Runeson det unika företaget Pratensis AB för att producera uteslutande svenska vildblomsfrön. De var oroliga över att naturliga gräsmarker, med vår tids snabba urbanisering och en växande gräsmattindustri, blivit särskilt sårbara och helt kunde försvinna. Inger och Mats ser växande vildblommor som ett effektivt sätt att bevara många av våra ängar. Frön samlas in direkt från inhemska växtsamhällen i olika distrikt i Sverige. Frönas genpool ändras löpande för att säkerställa bevarandet av genetisk variation. Det unika med Pratensis AB är att företaget koncentrerar sig på lokala växter som är extremt kostnadseffektiva och lämpliga för Sveriges nordliga klimat. Pratensis AB erbjuder frön och pluggplantor av ängsväxter.

Det finns minst 12 fröblandningar, som kan användas för olika mark- och ljusförhållanden. Till exempel är fröblandningar tillgängliga för: öppna, solexponerade och delvis skuggade förhållanden; för normala till torra jordar; fuktiga till våta jordar; torra kalkhaltiga jordar; för norra Sverige; annueller (för måleriska ängar); normala fuktiga jordar men i skuggiga förhållanden; torra havsnära ängar och fjällängar.

Fröblandningarna består av ängsgräs och ängsörter som vanligtvis börjar blomma under det andra året efter sådd. För att få en blommande effekt under det första året rekommenderar Pratensis AB att man lägger till vackra annuella arter, till exempel klintar och vallmor. Varje fröblandning innehåller 80 % gräs (minst fyra arter) och 20 % örtväxter (upp till 25 arter). Specifikationer om växtetablering och tillgången på växtblandningar kan erhållas från Pratensis hemsida: www.pratensis.se/froblandningar.

Exempel på fleråriga ängar som är etablerade med Pratensis-fröblandningar visas i figur 35–37.

Figur 38 visar ett exempel på användandet av fröblandningen *Normaläng* under en nioårsperiod. Inspirationen kommer från en frisk äng i Götaland och Svealand. Under 2008 var prästkrage *Leucanthemum vulgare*, sommarfibbla *Leontodon hispidus*, höskallra *Rhinanthus serotinus* och svartkämpar *Plantago lanceolata* de dominerande arterna. I augusti 2009 började rödklint *Centaurea jacea* och äkta johannesört *Hypericum perforatum* att synas. I juli 2010 anlände den första åkervädden *Knautia arvensisna*, medan rödklint *Centurea jacea*, prästkrage *Leucanthemum vulgare*, skallror *Rhinanthus* och lejonfibblor *Leontodon* fortfarande blommade synligt. I juli 2011 uppträdde stor blåklocka *Campanula persicifolia* och i juli 2012 fanns det ännu mer blåklockor *Campanula* och vädd *Knautia*, som tillsammans gav ett mycket vackert utseende. Under 2014–2016 var dessa arter fortfarande synliga på ängen.

Figur 35. Spetsamossen Park, Växjö. Den här ängen grundades våren 2014. Fotograferat i juli 2015. I denna blandning tillsattes en större mängd prästkrage *Leucanthemum vulgare* på landskapsarkitektens begäran. Foto: M.Ignatieva.

Figur 36. Växjöbostäder, Växjö. Ängen etablerades från en fröblandning 2013. Fotograferat i juli 2015. Foto: M.Ignatieva.

Figur 37. Berthåga kyrkogårds ängar, 2015. Dessa ängar grundades 1999–2000 (16 år gamla i detta foto). Foto: M.Ignatieva.

Figur 38. Äng i privat trädgård i Småland som såddes med blandningen "Normaläng" 2007. Bilderna visar gräsmattan från 2007 till 2016. Foto: I.Runeson.

PRATENSIS AB – "GRASS-FREE/TAPESTRY LAWN" (ÖRTGRÄSMATTA) I EN PRIVAT TRÄDGÅRD (SMÅLAND)

Etablerad i april 2014 och sedd den 29 maj 2015, ett år efter frösådd. En gräsfri fröblandning med bl.a. röllika *Achillea millefolium*, sandtrift *Armeria maritima*, liten blåklocka *Campanula rotundifolia*, backnejlika *Dianthus deltoides*, brudbröd *Filipendula vulgaris*, smultron *Fragaria vesca*, sommarfibbla *Leontodon hispidus*, rödfibbla *Pilosella aurantiaca* och gråfibbla *Pilosella officinarum* såddes i april 2014, totalt 29 arter. Ett år senare, i maj 2015, fanns mängder av tusensköna *Bellis perennis* och några styvmorsvioler *Viola tricolor*, gullviva *Primula veris* och sandtrift *Armeria maritima* blommade. Senare dominerade prästkrage *Leucanthemum vulgare*, rotfibbla *Hypochoeris radicata* och käringtand *Lotus corniculatus* (figur 39–40).

Figur 39. Örtgräsmatta, maj 2015 (ett år efter sådd). Foto: I.Runeson.

Figur 40. Klippning av örtgräsmattan, 29 juni 2015. Foto: I.Runeson.

SUNDBYBERG

Sundbybergs stad i Stockholms län beslutade att man skulle etablera tre typer av alternativa ängar norr om Lötsjön i parkområdet Golfängarna (figur 41–46). I april 2015 såddes tre fröblandningar som producerats av Pratensis AB: *humleblandning* (22 örtarter, 70 %, och fyra gräsarter, 30 %), *fjärilsblandning* (21 örtarter, 20 % och fem gräsarter, 80 %) och *örtängen* (18 örtarter, 100 %).

Figur 41. Placering av fröblandningarna i Sundbyberg. Foto: M.Ignatieva.

Figur 42. Jordpreparering och frösådd i Sundbyberg i april 2015. Foto: V.Kroon.

Figur 43. Juli 2015, tre månader efter sådd. Annueller (kornvallmo *Papaver rhoeas* och blåklint *Centaurea cyanus*) dominerade alla fröblandningar och drog till sig besökare. Foto: M.Ignatieva.

Figur 44. Humleblandningen i juli 2016, ett år efter sådd. Rödklint *Centaurea jacea*, prästkrage *Leucanthemum vulgare*, blåeld *Echium vulgare* och färgkulla *Anthemis tinctoria* dominerade blomningen. Foto: M.Ignatieva.

HUMLEBLANDNINGEN SÅDDES MED 3 G/M² OCH INNEHÖLL FÖLJANDE ARTER:

Örter:

Agrostemma githago (klätt)
Anthemis tinctoria (färgkulla)
Campanula persicifolia (stor blåklocka)
Centaurea cyanea (blåklint)
Centaurea jacea (rödklint)
Centaurea scabiosa (väddklint)
Echium vulgare (blåklint)
Galium verum (gulmåra)
Geum rivale (humleblomster)
Hypericum perforatum (johannesört)
Knautia arvensis (åkervädd)
Leucanthemum vulgare (prästkrage)
Linaria vulgaris (gulsporre)
Lotus corniculatus (käringtand)
Malva moschata (myskmalva)
Origanum vulgare (kungsmynta)
Papaver rhoeas (kornvallmo)
Primula veris (gullviva)
Rhinanthus minor (ängsskallra)
Silene dioica (rödblära)
Succisa pratensis (ängsvädd)
Verbascum nigrum (kungsljus)

Gräs*:*

Anthoxanthum odoratum (vårbrodd)
Briza media (darrgräs)
Festuca ovina (fårsvingel)
Festuca rubra (rödsvingel)

Figur 45. Örtgräsmatta. Prästkrage *Leucanthemum vulgare*, rödklint *Centaurea jacea*, väddklint *Centaurea scabiosa* och färgkulla *Anthemis tinctoria* dominerade blomningen i juli 2016. Foto: M.Ignatieva.

"GRASS-FREE/TAPESTRY LAWN" (ÖRTGRÄSMATTA) SÅDDES MED 1 G/M² OCH INNEHÖLL FÖLJANDE ARTER:

Örter:

Agrostemma githago (klätt)
Anthemis tinctoria (färgkulla)
Campanula persicifolia (stor blåklocka)
Centaurea cyanea (blåklint)
Centaurea jacea (rödklint)
Dianthus deltoides (backnejlika)
Filipendula vulgaris (brudbröd)
Galium verum (gulmåra)
Hypericum perforatum (johannesört)
Knautia arvensis (åkervädd)
Leontodon hispidus (sommarfibbla)
Leucanthemum vulgare (prästkrage)
Malva moschata (myskmalva)
Papaver rhoeas (kornvallmo)
Plantago lanceolata (svartkämpar)
Plantago media (rödkämpar)
Silene dioica (rödblära)
Viscaria vulgaris (tjärblomster)

Figur 46. Fjärilsblandning. Klintar, röllika och prästkragar var mest synliga. Juli 2016. Foto: M.Ignatieva.

Fjärilsblandningen såddes med 3,5 g/m^2 och innehöll följande arter:

Örter:

Achillea millefolium (röllika)
Achillea ptarmica (nysört)
Centaurea jacea (rödklint)
Centaurea scabiosa (väddklint)
Dianthus deltoides (backnejlika)
Helianthemum nummularium (solvända)
Hieracium umbellatum (flockfibbla)
Knautia arvensis (åkervädd)
Leontodon hispidus (sommarfibbla)
Leucanthemum vulgare (prästkrage)
Lotus corniculatus (käringtand)
Lychnis flos-cuculi (gökblomster)
Plantago lanceolata (svartkämpar)
Plantago media (rödkämpar)
Prunella vulgaris (brunört)
Rumex acetosa (ängssyra)
Rumex acetosella (bergsyra)
Scabiosa columbaria (fältvädd)
Solidago virgaurea (gullris)
Viola tricolor (svärmorsviol)
Viscaria vulgaris (tjärblomster)

Gräs*:*

Anthoxanthum odoratum (vårbrodd)
Festuca ovina (fårsvingel)
Festuca pratensis (ängssvingel)
Festuca rubra (rödsvingel)
Poa pratensis (ängsgröe)

Bild 47. Målerisk äng i Sundbyberg sommaren 2016. Foto: V. Kroon.

Sundbybergs besökare och parkförvaltare var särskilt imponerade av de annuella växternas blomning det första året. Nya måleriska ängar etablerades i Sundbyberg våren 2016, då med en klassisk mix (pictorialmeadows.co.uk/product/classic) med tolv arter av annueller, inklusive kornvallmo *Papaver rhoeas*, färgsporre *Linaria maroccana*, tigeröga *Coreopsis tinctoria* och draköga *Rudbeckia amplexicaulis* (figur 47).

Veg Tech

Veg Tech är det ledande företaget i Skandinavien som specialiserat sig på odling av inhemska växter och växtsamhällen och har varit verksamma sedan 1987. Veg Tech producerar miljövänliga gröna tak (sedum, vildblommor och gräs), gröna fasader och färdiga ängsmattor med naturliga örtartade växter för landskap, slänter och vattenmiljöer. Företaget producerar också vatten- och strandarter för naturlig dagvattenhantering, bevarande, restaurering av livsmiljöer och erosionsskydd. På samma sätt som Pratensis AB koncentrerar sig Veg Tech på att producera svenska växtmaterial på sina egna plantskolor i södra Sverige. Företaget erbjuder prefabricerade mattor, pluggväxter och frön (figur 48).

En av de populära lösningarna för snabb etablering av ängsvegetation är färdig ängsmatta bestående av en blandning av svenska örtartade växter och gräs. Sådana ängar odlas i ett 3–4 cm tjockt lager av jord, förstärkt vid basen med ett nät av kokosfibrer. Denna förstärkning gör mattan lätt att etablera. Olika kombinationer av växter möjliggör skapandet av ängar för olika typer av jord, fukt och solexponering.

Specifikationer för växtanläggning och tillgång till växtmaterial från Veg Tech kan erhållas från www.vegtech.se.

Figure 48. Veg Techs färdiga ängsmattor. Foto: M.Ignatieva.

Figur 49. Veg Techs färdiga ängsmattor. Foto: L. Pettersson

KAPITEL 5

Vår vision för alternativ till gräsmattor i Sverige

Vårt forskningsteams vision för alternativa gräsmattor i Sverige inspirerades av svenska naturliga ängar. Trots att Sverige fortfarande har ett betydande antal inhemska ekosystem har mängden gräsmark (naturlig och seminaturlig) minskat dramatiskt. Vår vision för alternativa gräsmattor är att skapa estetiskt tilltalande och kostnadseffektiva växtsamhällen med biologisk mångfald, baserade på den varierande inhemska svenska floran. Sådana biodiversa gräsmattor kan bidra till att återbörda ursprunglig natur till stadsmiljön. Vi samarbetar nära med Pratensis AB, som är pionjärer inom bevarandet av naturliga svenska gräsmarker och som främjar användningen av alternativa lösningar för gräsmattor, och med Veg Tech AB. Våra förslag till alternativ till gräsmattor överensstämmer med den nordiska naturens karaktär med dess blygsamma färg och struktur.

TYPER AV ALTERNATIVA GRÄSMATTOR SOM VI REKOMMENDERAR FÖR SVENSKA FÖRHÅLLANDEN (KOMMUNALA PARKER, FLERFAMILJSHUS OCH PRIVATA VILLOR):

1. ”Grass-free/tapestry lawns” (örtgräsmattor) skapade genom sådd och förkultiverade pluggplantor.
2. Perenna ängar (skapade genom sådd).
3. Måleriska annuella ängar (ängar skapade genom sådd).
4. Prefabricerade färdiga ängsmattor.

”Grass-free/tapestry lawn” (örtgräsmatta/gobeläng)

Den svenska versionen av örtgräsmattan är helt och hållet baserad på användningen av lämpliga inhemska fleråriga arter som kan ge en liknande nivå av täthet i växtmattan som en konventionell gräsmatta. Sådana örtgräsmattor kräver inte lika mycket klippning, eftersom dessa örter inte växer sig lika höga som gräs (figur 49). Örtgräsmattor kan etableras genom sådd av frön eller genom förkultiverade pluggplantor. Det snabbaste och mest effektiva sättet att etablera örtgräsmattor är att plantera förkultiverade pluggplantor som snabbt täcker marken, vilket minskar mängden ogräs. Nackdelen med denna metod är kostnaden (hög etableringskostnad), eftersom en tät matta behöver många växter. Men när en örtgräsmatta väl är etablerad kräver den mindre skötsel jämfört med en konventionell gräsmatta.

Om en örtgräsmatta skapas genom frösådd, kommer de fleråriga arterna att blomma först under andra säsongen. För den första säsongen kan man lägga till ettåriga annueller för att få en blomningseffekt. En tät matta uppnås först under tredje eller fjärde säsongen, beroende på lokala förhållanden och vädermönster. Men samtidigt som poängen med en sådan gräsmatta är att den är gräsfri är det ganska svårt att få den helt gräsfri, eftersom gräs kommer att leta sig in förr eller senare. Örtgräsmattan är en helt ny typ av yta, och i och med det behövs ytterligare forskning om vegetationsdynamiken.

Man kan gå på en örtgräsmatta när den väl är etablerad, men folk brukar vara försiktiga med att gå eller sitta på örtgräsmattor eftersom de är rädda att skada de vackra blommorna. Flera av de växtarter som rekommenderas för användning i Sverige finns dock redan i gamla konventionella gräsmattor, till exempel tusensköna *Bellis perennis*, brunört *Prunella vulgaris*, käringtand *Lotus corniculatus* och gåsört *Potentilla anserina*. Örtgräsmattor kan producera många blommor, vilket har en gynnsam effekt på pollinatörer.

Perenna ängar

Fleråriga ängar är gjorda av en blandning av inhemskt gräs och fleråriga örtartade växter (se fallstudier i kapitel 7). Valet av artskomposition (fröblandning) beror på befintliga markförhållanden, hydrologi, mikroklimat och, viktigast av allt, syftet och designintentionen. De mest framgångsrika biodiversa ängarna är etablerade på näringsfattiga marker (Andren, 2008).

Måleriska (annuella) ängar

Pratensis AB rekommenderar att man använder följande fröblandning för måleriska ängar: klätt *Agrostemma githago*, åkerkulla *Anthemis arvensis*, blåklint *Centaurea cyanus*, kornvallmo *Papaver rhoeas* och rågvallmo *Papaver dubium*.

Ett viktigt tips för framgångsrik etablering är att området som ska sås ska vara så fritt som möjligt från fleråriga ogräs. Annuella vildblommor är mer toleranta mot näringsrika jordar än vildväxande ängsblomarter (uppbyggda av blandningar av gräs och vildblommor), för vilka man rekommenderar etablering på mager jord (Lickorish *et al.*, 1997, Steel, 2013).

Måleriska ängar kan också etableras på befintliga jordar som bereds och där mager jord tillförs. Ett exempel på en sådan lösning är de måleriska ängarna i Sundbyberg.

Figur 49. Örtgräsmatta på demonstrationsplatsen på SLU Ultuna Campus i augusti 2016, tredje året efter att pluggplantorna planterades. Foto: M.Ignatieva.

Jordkvalitet

Forskare och praktiker i Europa och Sverige är alla övertygade om att den bästa jorden för att etablera ängar är mager mark utan vegetation eller rötter. Om jorden är bördig rekommenderas att:

1. **Ta bort ett lager** av den befintliga jorden (ca 15–20 cm) och ta in ny, mindre bördig jord. Om, av någon anledning, endast en del av ytjorden kan avlägsnas, blanda den befintliga jorden med den mindre bördiga jorden.

2. **Sprid ett lager** av mager jord (ca 30 cm) ovanpå den bördiga jorden när grästorven är borttagen.

3. **Förbered ytan** för sådd genom att jämna ut jorden. Glöm inte att ta bort stenar och rötter, eftersom de kan försvåra skötseln i framtiden.

Att så och sätta pluggplantor

TIDPUNKTEN FÖR SÅDD

Den bästa tiden att så är i augusti eller september. I de sydligaste delarna av Sverige kan oktober också vara en bra tid. Fröblandningar kan också sås tidigt på våren (april eller maj). Att så under sen vår eller tidig sommar kan dock kräva bevattning, speciellt vid en torr senvår eller tidig sommar.

Rekommenderad mängd frö är endast ca 3–3,5 g/m². Därför bör frön blandas med ett lämpligt utfyllnadsmedel, som sågspån, vetegroddar eller sand, för att säkerställa en jämn fördelning av frön på ytan. Detta hjälper också till att se var frön har såtts. Se till att fröna inte sjunker ner för djupt. Använd en kratta väldigt lätt för att hjälpa fröna att sätta sig i marken. Håll området fuktigt i några veckor.

Om avsikten är att så stora områden, kan sprutsådd vara effektivt (figur 51). Det behövs ingen gödsel i sprutsådd (vilket normalt tillsätts vid sådd av gräsarter för exempelvis vägslänter).

Under det första året blommar bara annuellerna, men under de kommande åren kommer fler och fler arter att blomma och annuellerna kommer att försvinna.

PLANTERINGSRÅD

Det är möjligt att plantera pluggplantor som ett komplement till ängsfrön för att få en blommande äng första sommaren. Våra experiment har visat att en kombination av sådd och pluggplantor ger bästa resultat (figur 50). Ängen kommer att ha en dekorativ effekt redan under den första sommaren. Pratensis AB föreslår att man planterar 4–5 plantor/m² utöver standardsådden på 3–3,5 g/m². Växter ska planteras i små grupper (minst tre exemplar i varje grupp) och slumpmässigt spridas över ängen. Pluggplantor kan planteras före eller efter sådd. Plantering av ängsväxter kan ske under hela växtsäsongen, normalt från april till slutet av oktober. I vissa regioner råder tidig sommartorka och då är hösten eller sensommaren att föredra.

Figur 50. Örtgräsmatta vid Ultuna Campus i juli 2014, tredje månaden efter pluggplantornas plantering. Foto: M.Ignatieva.

Figur 51. Sprutsådd av ängs-blandningar i Växjö, april 2017. Foto: I.Runeson, Pratensis AB.

KAPITEL 6

Metod för att etablera biodiversa alternativ till gräsmatta

Våra rekommendationer bygger på erfarenheterna av att etablera alternativa gräsmattor från Pratensis AB (se bolagets hemsida www.pratensis.se) och alternativa gräsmattor på Ultuna Campus, SLU, Uppsala, 2014–2017 (www.slu.se/lawn).

Platsförberedelse

För de flesta typer av alternativa gräsmattor rekommenderas en solexponerad plats med mager, väldränerad jord. Praktisk erfarenhet visar att bördig jord främjar högre örter och högt gräs och att mindre arter inte kommer att kunna konkurrera där. Höga fosforhalter har också en negativ inverkan på många vildväxande ängsblommor. Vi rekommenderar att man kontrollerar det potentiella området för alternativ till gräsmatta för att säkerställa att det inte har många rotspridda ogräs som tistlar *Cirsium arvense*, kvickrot *Elytrigia repens* och kirskål *Aegopodium podagraria*. Ett sätt att minska ogräsen är att låta marken ligga i träda ett år innan sådd.

De bästa resultaten uppnås när befintlig konventionell gräsmatta kan avlägsnas och vid behov ny jord tillsättas (i vissa fall kan man använda den befintliga jorden). Denna metod innebär initialt en stor ekonomisk investering, men garanterar framgång för etableringrn av den alternativa gräsmattan. Det har visat sig att den metod för att förvandla en konventionell gräsmatta till ängsmark som går ut på att man avlägsnar små rutor av grästorv och sedan sår frön i rutorna, inte fungerar lika bra som att avlägsna all befintlig grästorv på en gång.

Skötsel och underhåll

Under det första året förekommer många annuella ogräs i jorden. Dessa ogräs kan skäras ner till 8–10 cm innan fröna har mognat (om arterna är oönskade på ängen). Ogräsrensning för hand rekommenderas för de svåraste ogräsen. Perenna blommande ängsarter blommar inte under det första året, vilket är anledningen till att en nysådd äng ofta är ganska oattraktiv med många öppna jordfläckar. Diverse annuella ogräs är de dominerande växterna under det första året, på grund av sin överlevnadsstrategi och tillgänglighet i fröbanken. Men flera ängsvildblommor sprider sig under det första året. Under det andra året kommer de första vildblommorna att börja blomma och ogräset minskar; då består ängsskötseln av årlig klippning i slutet av sommaren, när de flesta av plantorna har blommat ut. Klippning av ängar kan ske från slutet av juli eller i augusti och kan utföras även under september. Klippet måste avlägsnas, antingen direkt eller efter några dagar. För små områden kan en lie ge bra resultat. För stora ängsområden används vanligtvis maskiner. Klipphöjd för äng och örtgräsmatta är ca 5–10 cm. Klipphöjden är också beroende av vilken typ av skärverktyg som används (figur 52–54).

Andra verktyg för att klippa ängar är röjsågar med mycket vasst blad eller grästrimmer. Små områden med örtgräsmatta kan klippas med trädgårdssax.

Figur 52. Slagning av en liten äng med en lie. Foto: I.Runeson, Pratensis AB.

Figur 53. Klippning med en slåtterbalk på en större äng. Foto: I.Runeson, Pratensis AB.

Figur 54. Klippning med hjälp av gräs-trimmer med vasst blad. Foto: I.Runeson, Pratensis AB.

Tillväxttid

De äldsta sådda ängarna som etablerats av Pratensis AB är nu cirka 25 år. Om ängarna sköts på rätt sätt och sås på mager mark, kan de fortsätta att fungera riktigt bra under en mycket lång tid. Många av de svenska naturliga ängarna är flera hundra år gamla. Ängens utseende kan förändras från år till år på grund av vegetationens dynamiska karaktär och påverkan av väderfaktorer.

En annan mycket bra teknik, som används i många länder, är att kombinera ängar med klippta områden av konventionella gräsmattor (se kapitel 4, avsnittet "Cues to care" (Tecken på omsorg), samt figur 55).

Ekonomi

Kostnaden för fröerna som sås på en äng är ca 3–4 kr/m^2. Lägger man till kostnaden för pluggplantor blir den totala kostnaden ca 80–100 kr/m^2 (personlig kommunikation med Inger Runeson, Pratensis AB, 4 april 2017).

Figur 55. "Cues to care" (tecken på omsorg) i Uppsala. Juni 2015. Foto: M.Ignatieva.

KAPITEL 7

Fallstudier

De första experimentella alternativa gräsmattorna i Kunskapsparken (Ultuna Campus, SLU, Uppsala) etablerades våren 2014. Under våren 2016 tillkom tre experimentytor, inom ramen för SLU:s klimatfondsprojekt ”Mot hållbara gräsmattor: sökandet efter alternativa kostnadseffektiva och klimatvänliga gräsmattor på Ultuna Campus” (figur 57). Projektet var en fortsättning på vårt Formas-finansierade projekt ”Gräsmattor som ekologiskt och kulturellt fenomen” (se kapitel 1).

Plats 1: Första försöken med alternativ till gräsmatta med försöksrutor (1,5 m x 1,5 m)

De första försöksrutorna (två typer av ört-gräsmatta, fjärilsblandning, humleblandning, kalkrik äng, torra ängar, målerisk äng, grus-gräsmatta och klövergräsmatta, upprättades våren 2014 (figur 56). Såväl frösådd som plantering av pluggplantor användes. Pratensis AB Sverige donerade allt växtmaterial. Humleblandningen är en blandning av arter som är attraktiva för humlor, till exempel blåeld *Echium vulgare* och gulmåra *Galium verum*. Grusgräsmattan skapdes på den hårdaste jorden med högt grusinnehåll, med hjälp av växter som kattfot *Antennaria dioica*, rotfibbla *Hypochaeris radicata* och harklöver *Trifolium arvense*. För ytterligare information, se LAWN-projektets hemsida: www.slu.se/lawn.

Figur 56. Försök med alternativ till gräsmatta vid Ultuna, i juli 2015 (ett år efter sådd). Foto: M.Ignatieva.

PLATSER:
1: Försöksrutorna
2: Örtgräsmattan
3: Den svenska ängen
4: Äng med picknick-bänk

Figur 57. Kunskapsparkens placering på SLU Ultuna Campus med de experimentella platserna för alternativa gräsmattor. Grafik: J.Lööf Green.

Plats 2: Exempel på örtgräsmatta vid Ultuna Campus SLU, etablerad i april 2016

Vår örtgräsmatta (410 m²) är inspirerad av den medeltida idén om Edens lustgård med informella ”blommande ängar” eller ängar planterade med ett stort urval av aromatiska örter och blommor. Syftet är att förbättra den biologiska mångfalden och att återvända till naturen. Denna gräsmatta består av 30 örtväxter som är inhemska, vilket kan ge den effekten att man får en lågväxande blommande matta som kan användas för rekreation och som bara behöver klippas 2–3 gånger under sommarsäsongen (figur 58). Pratensis AB och Veg Tech förság oss med växtmaterial till denna plats. Innan örtgräsmattan skapades var detta område täckt av konventionell gräsmatta, som klipptes 16 gånger per säsong.

SKÖTSELPLAN FÖR 2017

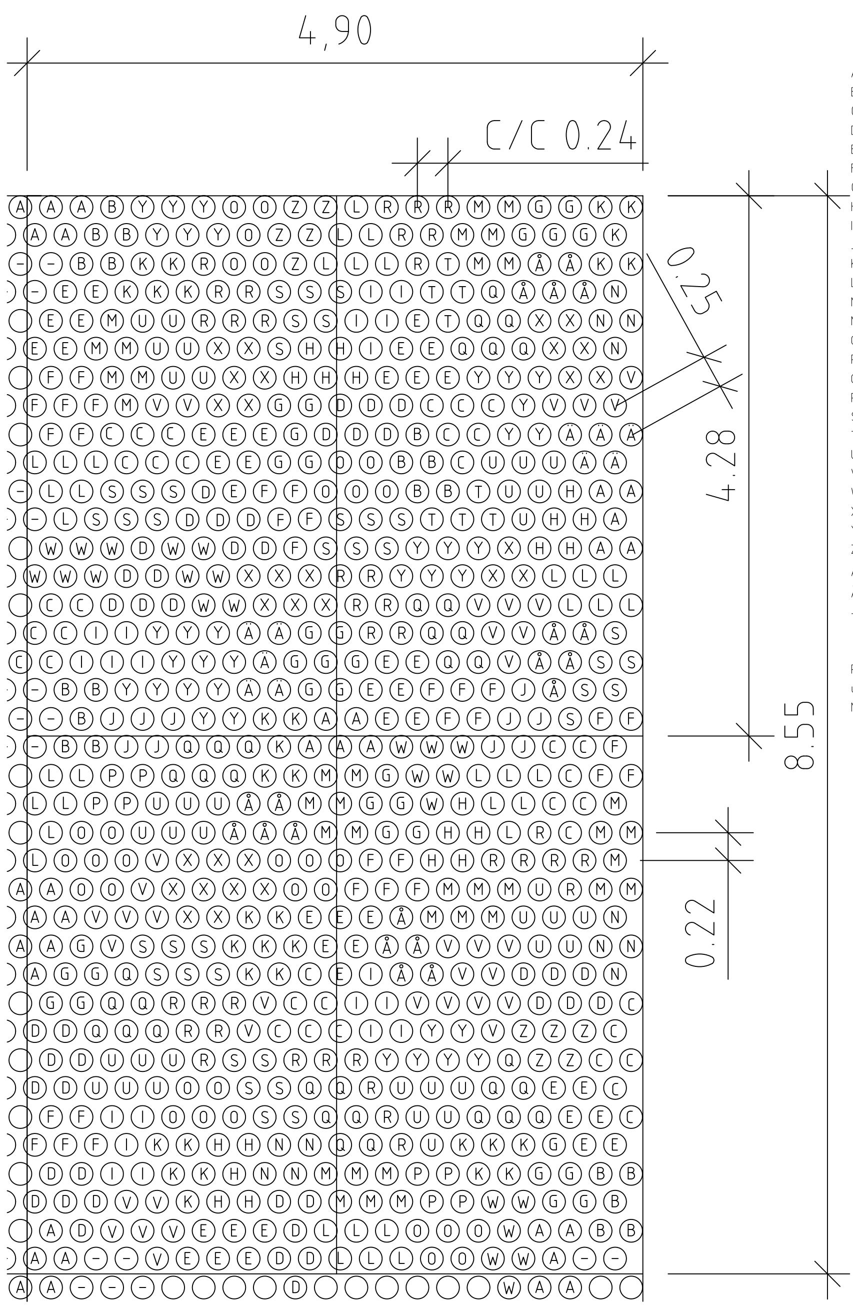
Att göra	Månad	Förväntad tidsåtgång
Klippa döda grenar och rensa löv från hösten	Mars	3 timmar
Ogräsrensning	Juni, juli, augusti	4 timmar
Klippning till 10 cm och ta bort klippet	Juni., augusti	3 timmar
Ta bort förna	Maj-augusti	1 timme

KOSTNADSBERÄKNING FÖR SKÖTSEL AV ÖRTGRÄSMATTA ÄR ENLIGT FÖLJANDE

- 1 klippning: 500 kr per gång (plus kostnad för maskiner).
- Trimning av kanter: 200 kr per gång (varannan gång).
- Vattning, gödning och vertikal skärning: 2 000 kr.
- Totalt: cirka 12 000 kr.

FÖRVÄNTNINGAR INFÖR 2017-2019

Vi förväntar oss att örtgräsmattan 2018–2019 kommer att se ut som vår första örtgräsmatta i försökrutan i Kunskapsträdgården (1,5 m x 1,5 m) (figur 65). Örtgräsmattan har visat på väldigt god utveckling under våren och sommaren 2017 (året efter etablering), (figur 66-68).



FÖRKLARINGAR

A, Achillea millefolium, rölleka
B, Antennaria dioica, kattfot
C, Armeria maritima, trift
D, Campanula rotundifolia, liten blåklocka
E, Dianthus deltoides, backnejlika
F, Filipendula vulgaris, brudbröd
G, Fragaria vesca, Smultron
H, Galium verum, gulmåra
I, Helianhemum nummularium, solvända
J, Leontodon hispidus, sommarfibbla
K, Leucanthemum vulgare, prästkrage, sen
L, Pilosella aurantiaca, rödfibbla
M, Pilosella officinarium, gråfibbla
N, Polygala vulgaris, jungfrulin
O, Potentilla anserina, gåsört
P, Potentilla erecta, blodrot
Q, Potentilla tabernaemontanii, småfingerört
R, Primula veris, gullviva
S, Saxifraga granulata, mandelblomma
T, Sedum telephium, kärleksört
U, Silene uniflora, strandglim
V, Thymus serpyllum, backtimjan
W, Veronica officinalis, ärenpris
X, Veronica spicata, axveronika
Y, Viola canina, ängsviol
Z, Viola odorata, luktviol
Å, Viola tricolor, styvmorsviol
Ä, Viscaria alpina, fjällnejlika
–, Växt från intillliggande yta

Planteringen ska se slumpartad ut men ska upplevas som ett lapptäcke. Mer detaljerad förklaring finns i bilaga 1.

Figur 58. Planteringsplan för örtgräsmatta. April 2016. Grafik: J.Lööf Green.

VÄXTLISTA FÖR PLATS 2: ÖRTGRÄSMATTA

Achillea millefolium (röllika)
Antennaria dioica (kattfot)
Armeria maritima (trift)
Bellis perennis (tusensköna)
Campanula rotundifolia (liten blåklocka)
Dianthus deltoides (backnejlika)
Filipendula vulgaris (brudbröd)
Fragaria vesca (smultron)
Galium verum (gulmåra)
Helianthemum nummularia (solvända)
Leontodon hispidus (sommarfibbla)
Leucanthemum vulgare (prästkrage)
Lychnis alpina (fjällnejlika)
Pilosella aurantiaca (rödfibbla)
Pilosella officinarum (gråfibbla)
Polygala vulgaris (jungfrulin)
Potentilla anserina (gåsört)
Potentilla erecta (blodrot)
Potentilla tabernaemontani (småfingerört)
Primula veris (gullviva)
Prunella vulgaris (brunört)
Saxifraga granulata (mandelblomma)
Silene uniflora (strandglim)
Sedum telephium (kärleksört)
Thymus serpyllum (backtimjan)
Veronica officinalis (ärenpris)
Veronica spicata (axveronika)
Viola canina (ängsviol)
Viola odorata (luktviol)
Viola tricolor (svärmorsviol)

ETABLERING OCH PLANTERING AV ÖRTGRÄSMATTA (FIGUR 59–64)

Befintlig grässvål och 15 cm jord avlägsnades från platsen. Därefter lades en ny jordblandning på. Denna jordblandning tillhandahölls av Hasselfors och bestod av 50 % krossad granit (0–4 mm) och 50 % natursand (0–8 mm) som blandades med ytterligare 50 volymprocent mörk torv. Hasselfors tillhandahöll jord för hela försöksplatsen. Ingen kalk eller gödning användes.

Figur 59. Avlägsnande av konventionell gräsmatta. Avlägsnade gräsbitar återanvändes i andra campusområden. Foto: M.Ignatieva.

Figur 60. Förfarande för avlägsnande av den konventionella gräsmattan. April 2017. Foto: M.Ignatieva.

Figur 61. Spridning av specialtillverkad mager jord från företaget Hasselfors Garden. Foto: M.Ignatieva.

Figur 62. Pluggplantorna sätts ut. Foto: M.Ignatieva.

Figur 63. Örtgräsmattan i början av maj. Foto: M.Ignatieva.

Figur 64. Örtgräsmattan i juli 2016 . Foto: M.Ignatieva.

Figur 65. Örtgräsmatta i försöksrutorna (plats 1) under andra året efter etableringen (juni 2016). Foto: M.Ignatieva.

Figur 66. Örtgräsmatta (plats 2) i slutet av maj 2017, ett år efter etablering. *Primula veris* (gullviva), *Armeria maritima* (trift), *Viola tricolor* (svärmorsviol) och *Bellis perennis* (tusensköna) blommar. Foto: M.Ignatieva.

Figur 67. Örtgräsmatta (plats 2) i början av juni 2017, ett år efter etablering. *Armeria maritima* (trift) är i full blom. Foto: M.Ignatieva.

Figur 68. Örtgräsmatta (plats 2) den 22 Juni 2017. *Leucanthemum vulgare* (prästkrage) och *Pilosella aurantiaca* (rödfibbla) är de mest framträdande arterna. Foto: M.Ignatieva.

ARTER OCH BLOMNINGSKALENDER FÖR ÖRTGRÄSMATTA (MAJ–SEPTEMBER)

Under svenska förhållanden kan örtgräsmattor ge en blommande effekt från maj till september (figur 69).

Figur 69. Blomningskalender för örtgräsmatta. Foto: M.Ignatieva.

MAJ	JUNI	JULI	AUGUSTI	SEPTEMBER
Armeria maritima (trift)	*Silene uniflora* (strandglim)	*Dianthus deltoides* (backnejlika)	*Veronica officinalis* (ärenpris)	*Achillea millefolium* (röllika)
Primula veris (gullviva)	*Fragaria vesca* (smultron)	*Thymus serpyllum* (backtimjan)	*Veronica spicata* (axveronika)	*Galium verum* (gulmåra)
Viola tricolor (svärmorsviol)	*Armeria maritima* (trift)	*Galium verum* (gulmåra)	*Potentilla erecta* (blodrot)	*Leontodon hispidus* (sommarfibbla)
Viola odorata (luktviol)	*Viola canina* (ängsviol)	*Potentilla anserina* (gåsört)	*Pilosella aurantiaca* (rödfibbla)	*Sedum telephium* (kärleksört)
Viola canina (ängsviol)	*Prunella vulgaris* (brunört)	*Pilosella aurantiaca* (rödfibbla)	*Achillea millefolium* (röllika)	*Thymus serpyllum* (backtimjan)
Bellis Perennis (tusensköna)	*Pilosella officinarum* (gråfibbla)	*Leontodon hispidus* (sommarfibbla)	*Campanula rotundifolia* (liten blåklocka)	*Campanula rotundifolia* (liten blåklocka)
Fragaria vesca (smultron)	*Bellis perennis* (tusensköna)	*Campanula rotundifolia* (liten blåklocka)		
Saxifraga granulata (mandelblomma)				

Plats 3: Den svenska ängen

Platsen med vår svenska äng (390 m²) är inspirerad av traditionella svenska lövängar (ängar bland fruktträd). Den ursprungliga platsen för Kunskapsparken bestod av körsbärsträd planterade på en traditionell gräsmatta som klipptes många gånger per säsong. Syftet med plats 3 är att visa på skönheten hos de inhemska svenska ängsväxterna och deras potential för biologisk mångfald och för användning i undervisning om miljön. Den ängsfröblandning som här användes bestod av 30 inhemska arter (17,5 % örter och 82,5 % gräs) och tillhandahölls av Pratensis AB.

VÄXTLISTA FÖR PLATS 2

Örter:

Achillea millefolium (röllika)	*Cichorium intybus* (cikoria)	*Leontodon hispidus* (sommarfibbla)	*Potentilla tabernaemontani* (småfingerört)
Anthemis tinctoria (färgkulla)	*Echium vulgare* (blåeld)	*Leucanthemum vulgare* (prästkrage)	*Primula veris* (gullviva)
Campanula persicifolia (stor blåklocka)	*Filipendula vulgaris* (brudbröd)	*Lotus corniculatus* (käringtand)	*Rhinanthus minor* (ängsskallra)
Campanula rotundifoilia (liten blåklocka)	*Galium verum* (gulmåra)	*Malva moschata* (myskmalva)	*Saxifraga granulata* (mandelblomma)
Centaurea jacea (rödklint)	*Hypericum perforatum* (äkta johannesört)	*Origanum vulgare* (kungsmynta)	*Scabiosa columbaria* (fältvädd)
Centaurea scabiosa (väddklint)	*Hypochoeris maculata* (slåtterfibbla)	*Plantago media* (rödkämpar)	*Silene nutans* (backglim)

Gräs:

Helictotrichon pratensis (ängshavre)	*Festuca ovina* (fårsvingel)	*Phleum phleoides* (flentimotej)
Briza media (darrgräs)	*Festuca rubra* (rödsvingel)	*Phleum pratense ssp. bertoloni* (ängstimotej)

SKÖTSELPLAN FÖR 2016

Eftersom denna ängsblandning huvudsakligen består av fleråriga arter, kommer det mesta inte att blomma under det första året. Några annueller ingår för att ge lite blomning under det första året (figur 72).

Ängen bör klippas en gång om året, på sensommaren (i början av augusti), till 6–8 cm och klippet måste avlägsnas. För fleråriga ängar bör gödselmedel aldrig appliceras.

Att göra	Månad
Vattning efter plantering, 2 gånger per vecka i 1 timme för de första 3 veckorna efter sådd, 1-2 gånger under resten av säsongen	I slutet av maj till början av juni om det är en väldigt torr vår eller tidig sommar
Ogräsrensning, ca 1 timme per gång	Juni (1), juli (1), augusti (2) Totalt 5 timmar

SKÖTSELPLAN FÖR 2017

Klippa och ta bort klippet en gång per säsong (i slutet av augusti).

ETABLERINGEN AV PLATS 3: DEN SVENSKA ÄNGEN (FIGUR 70–71)

Befintlig grästorv togs bort från platsen. Samma jordblandning som för plats 2 användes här och levererades av Hasselfors (50 % krossad granit (0–4 mm) och 50 % natursand (0–8 mm), blandat med ytterligare 50 volymprocent mörk torv).

Figur 70. Områdesetablering, April 2016. Foto: M.Ignatieva.

Figur 71. Sådd i maj 2016. Foto: M.Ignatieva.

Figur 72. Den svenska ängen med sina blommande annueller i juli 2016. Foto: M.Ignatieva.

FÖRVÄNTNINGAR 2017 FÖR PLATS 3

Som vi förväntat oss, visade perennerna i den svenska ängen på en imponerande blomning under sommaren 2017 (figur 73).

Figur 73. Den svenska ängen under det andra året efter sådd, juni 2017. *Lotus corniculatus* (käringtand), *Echium vulgare* (blåeld) och *Leucanthemum vulgare* (prästkrage) är i full blom. Foto: M.Ignatieva.

Plats 4: Äng med ängspicknickbänk

Inspirationen till den här platsen på 68m² kom från de medeltida trädgårdarna med sina blommande ängar och grästorvsbänkar. Färdiga ängsmattor, levererade av Veg Tech, bestod av 16 arter lågväxande perenner och grässorter (60 % örter och 40 % gräs). Den här typen av färdiga ängsmattor är designade för att användas i tuffa urbana miljöer och tål både uttorkning och exponering för salt.

Konstruktörerna av bänken använde lärk. Bänken var ett gemensamt projekt av Simon Lindberg och John Lööf Green. Krossad sten, som användes vid etableringen av ängen, användes även i bänkens sittyta. De färdiga ängsmattorna placerades ovanpå den krossade stenen.

VÄXTLISTA FÖR PLATS 4

Örter:

Achillea millefolium (röllika)
Armeria maritima (sandtrift)
Dianthus deltoides (backnejlika)
Hieracium pilosella (gråfibbla)
Galium verum (gulmåra)
Linaria vulgaris (lin)
Lotus corniculatus (käringtand)
Rumex acetosella (bergsyra)
Plantago maritima (gulkämpar)
Potentilla argentea (femfingerört)
Silene uniflora (strandglim)
Veronica officinalis (ärenpris)
Veronica spicata (axveronika)
Viola tricolor (styvmorsviol)

Gräs:

Festuca ovina (fårsvingel)
Agrostis capillaris (rödven)

SKÖTSELPLAN FÖR 2016

Att göra	Månad
Vattning efter plantering, 2 gånger per vecka i 3 timmar för de första 3 veckorna efter plantering, en gång i veckan för de kommande 3 veckorna	I slutet av maj-början av juni om väldigt torr vår och tidig sommar
Klippning och ta bort klippet	September

SKÖTSELPLAN FÖR 2017

Klippning och ta bort klippet (i september).

ETABLERING AV PLATS 4 (FIGUR 74–78)

- Avlägsnande av befintligt gräs
- Applicering av krossad sten (0–16 mm)
- Applicering av turfgräs från Veg Tech AB
- Picknickbänken: studentprojekt av Simon Lidberg och John Lööf Green.

Figur 74. Etablering av platsen i april 2016.
Foto: M.Ignatieva.

Figur 76. Installation av picknickbänk.
Foto: M.Ignatieva.

Figur 75. Plats 4 i juli 2016. De mest synliga växterna är *Dianthus deltoides* (backnejlika) och *Lotus corniculatus* (käringtand). Foto: M.Ignatieva.

Figur 77. Picknickbänken i juli 2016. Foto: M.Ignatieva.

Figur 78. Picknickbänken i augusti 2016. Foto: M.Ignatieva.

KAPITEL 8

Designförslag för Göteborg och Malmö

Följande förslag till design av alternativa gräsmattor presenteras av två studentprojekt vid SLU rörande design av gräsmatta med ekologiskt tänkande för två befintliga bostadsområden i Göteborg och Malmö; ett examensarbete av Andersson & Bergbrant, 2015 samt ett designförslag för Malmö utformat av J.L. Green, 2016. Förslagen betonar medvetet möjligheten att använda olika typer av alternativa gräsmattor även i små kvartersgårdar. En grundlig inventering (funktion, mikroklimat, vegetation, mark och platsens upplevelsevärden) samt en platsanalys ligger till grund för dessa designförslag.

Göteborg

Designförslaget för alternativa gräsmattor i Göteborg utgick från:

1. *Göteborgs övergripande plan* (Översiktsplan för Göteborg, 2014), som lyfte fram möjligheter att skapa en attraktiv stadsmiljö som kännetecknas av ”komplexitet med blandning av funktioner, en visuell täthet och möjligheter till interaktion mellan människor” (s. 35).
2. *Grön strategi* (2014), visionen för de närmaste 20 åren, där Göteborg ses som en tät grön stad med en hälsosam stadsmiljö, rik flora och fauna och en fullständig tillgång till ekosystemtjänster.

Den föreslagna platsen för omformning ligger i sydvästra delen av Lundby, en av de snabbast växande distrikten i Göteborg (figur 79). Det är ett bostadsområde med flerfamiljshus från 1950-talet (folkhem). Före det var det gammal betesmark. Det finns två parkområden och stora bostadsgårdar, täckta huvudsakligen av konventionella gräsmattor, några planteringar och bänkar (och lekredskap). Det finns också en stenig kulle på platsen. Från analysen drogs slutsatsen att ”parkområdena hade stora gräsmattor som var för stora i förhållande till hur mycket de används. Fler funktioner kan läggas till bostadsgårdarna och de stora restytorna, särskilt mer ekologiska funktioner” (Andersson & Bergbrant, 2015, s. 72).

Figur 79. Exempel på vegetation och livsmiljöförteckning. Analys visade att stora delar av grannskapet är relativt homogena med stora områden med konventionella gräsmattor och ett fåtal trädslag.

Figur 80. Det övergripande designförslaget för platsen som visas i figur 79.

Syftet med den föreslagna designen (figur 80) var att omvandla ett homogent bostadsområde dominerat av konventionell gräsmatta till ett område med högt upplevelsevärde för alla sinnen och med höga ekologiska och biologiska värden. Förslaget innehåller en större mångfald av livsmiljöer, som örtgräsmatta, målerisk äng och olika ängar. Andra typer av vegetation, såsom träd, buskar och odlingsytor, har lagts till för att komplettera gräsytor med rumsliga egenskaper, olika livsmiljöer och en övergripande ökning av vegetationens heterogenitet. Vissa områden av konventionell gräsmatta och kanter av områden har omvandlats till äng eller högt gräs. Konventionella gräsmattor har fortfarande sin plats i grannskapet. Principen om ”Cues to care” (tecken på omsorg) tillämpas i flera fall för att visa att dessa områden tas omhand och inte försummas.

En av de viktiga principerna för den föreslagna strategin är användningen av främst inhemska växter, som främjar lokala biotoper. Denna princip kombineras med användandet av återvunnet material, såsom bänkar och bord.

Ett annat förslag var en ”labyrint av normaläng” (figur 81). Från en lekplats på västra sidan sträcker sig en halvcirkel av konventionell gräsmatta i ängen och utökar lekplatsens yta. Detta element ger en tydlig identitet till norra parkområdet och skiljer det från det södra. De klippta vägarna och kanterna mot gångarna sköts som en konventionell gräsmatta, för att säkerställa tillgänglighet för människor och kommunicera att området är omhändertaget.

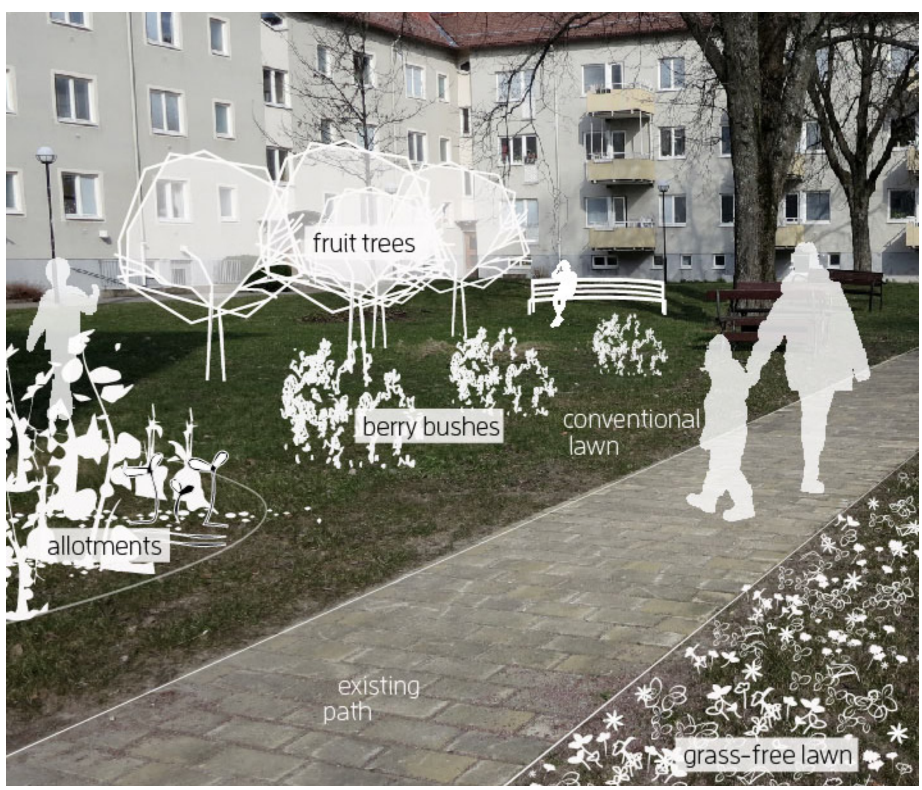
Förslaget med målerisk äng (figur 82) ger en stark identitet till den här delen av parken. Den långa blomningstiden ger en intressant utsikt från byggnadens fönster och är också till nytta för pollinatörer. Den konventionella gräsmattan bevaras bredvid gångvägar och intill dagisbyggnaden, liksom mellan de två områdena, så att människor kan komma nära och se blommorna

Figur 81. ”Labyrint av normaläng”.

och djurlivet. En förklaringstavla finns mellan de två områdena.

Ett förslag med olika ”lager av vegetation” (figur 83) gjordes för gårdar i syfte att förbättra ekologiska värden och upplevelsevärden.

Figur 82. Förslaget ”Pictorial meadow” (målerisk äng).



Figur 83. Förslaget ”Layers of vegetation” (Lager av vegetation).

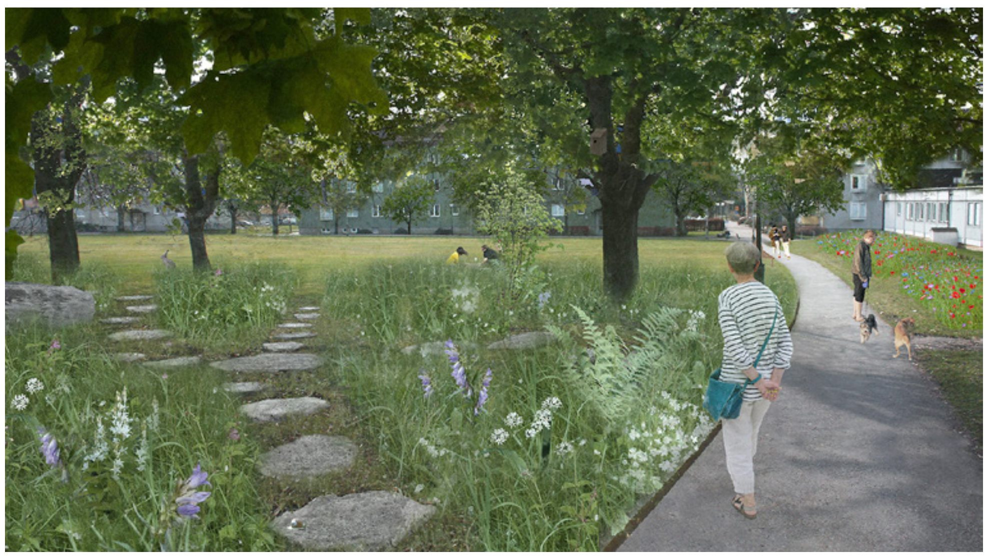
Förslaget till skogsbryn (figur 84) är inspirerat av begreppet "naturligt intilliggande skog" och syftar till att öka upplevelsen av naturen nära husen. Konventionell gräsmatta intill högt gräs ger plats för aktivitet.

Förslaget "ängsgård" (figur 85) syftar till att förvandla större delen av innergården till gemensam äng med stigar av konventionell gräsmatta och gångvägar. Den föreslagna designen skapar en mängd upplevelsevärden och bidrar till ökad biologisk mångfald.

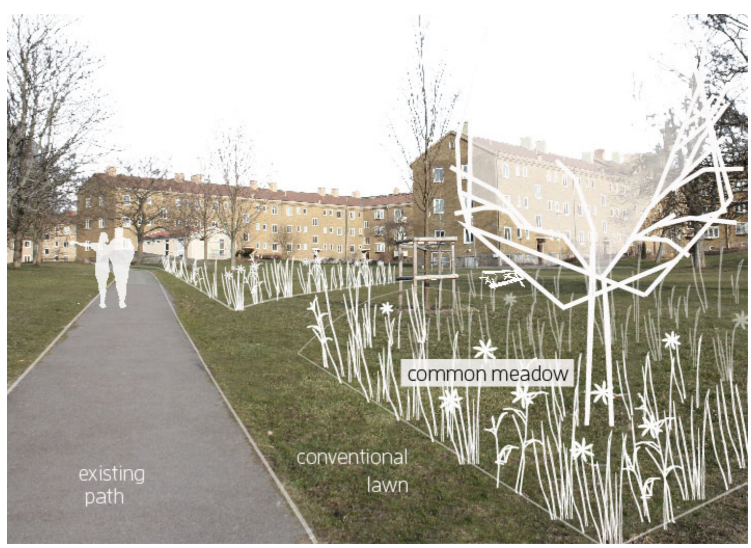
Andra designförslag för Lundby visas i figurerna 86–90.

Figur 84. Förslaget "Forest edge" (skogsbryn).

Figur 85. Befintlig innergård och hur innergården kommer att se ut om tre år enligt förslaget.



Figur 86. Förslaget "Grove meadow" (ängsdungen). Trampstenarna kan locka människor att komma in i denna skuggade äng och uppleva växtligheten.



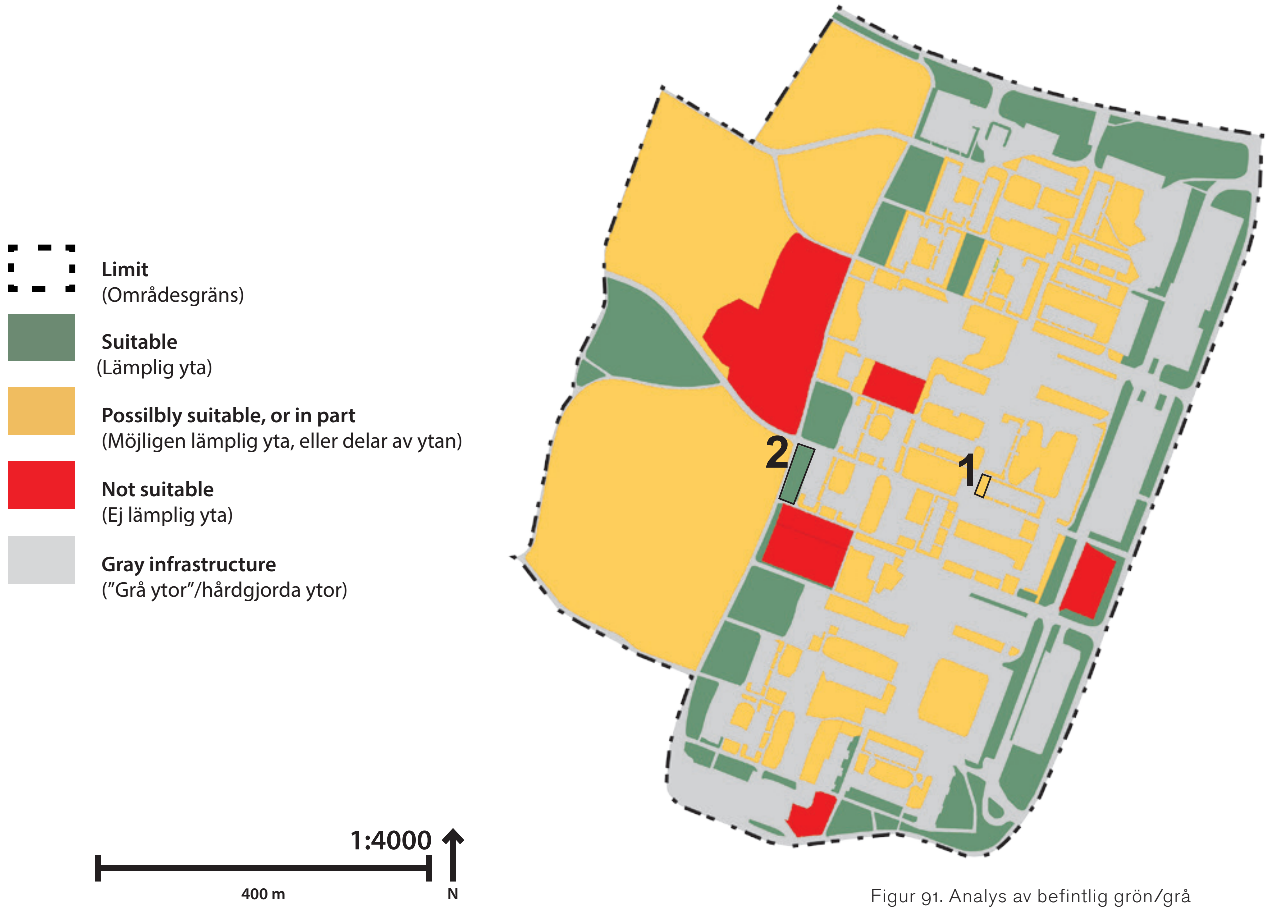
Figur 87. Förslaget "Triangular meadow" (triangulär äng) i den södra parken.

Figur 88. Inventering av en plats lämplig att omvandlas till en alternativ "Pictorial meadow and high grass walkway" (målerisk äng och höggräsgångväg).

Figur 89. Förslag till det första året: bökande grisar kan hjälpa till att förbereda jorden för den måleriska ängen och höggräsgångväg.

Figur 90. Förslaget till målerisk äng och höggräsgångväg efter 10 år.

Den övergripande designen ger platsen ett syfte och gör den till ett värdefullt grönområde nära bostadsområden där människor kan mötas och tillbringa tid. En av de väsentliga förutsättningarna för ett eventuellt genomförande av designförslaget i Lundby är att medborgare, kommunala och lokala chefer och landskapsarkitekter är delaktiga i design- och implementeringsprocessen.



Figur 91. Analys av befintlig grön/grå infrastruktur och områden lämpliga för etablering av alternativa gräsmattor. Område 1 och 2, se figur 92-93 på s. 82. (J.Lööf Green, 2016).

Malmö: Holma, ett miljonprogram-område

Inventeringar och analyser genomfördes sommaren 2015. I bostadsområden från miljonprogrammet är gräsmattor det dominerande landskapselementet. Holma i Malmö är inget undantag. Under sommaren 2015 gjordes en kort undersökning av området för att utvärdera var det var lämpligt att etablera alternativa gräsmattor. Förslagen tog hänsyn till de sociologiska studier som genomfördes av LAWN-projektet 2015.

Undersökningen började med en inventering av platsens grönområden, där gräsmattor utgör den dominerande delen. Gräsmattor som enligt sociala undersökningar användes ganska intensivt (till sport, picknick och lek) beaktades och kartlades. Dessa områden används även fortsättningsvis som konventionella gräsmattor. Gräsmattor intill byggnader, och speciellt byggnaders ingångar, ansågs lämpliga för vissa alternativa lösningar, men med vissa begränsningar, exempelvis beträffande plantornas höjd och bredden på klippta kanter. Några delar av Krokbäcksparken med sina kullar kan också utvecklas, så länge fritidsanvändningen av området respekteras. Slutligen föreslogs resten av de gröna ytorna i bostadsområdet, som inte används, eller ytor som gränsar till byggnadsingångar som lämpliga för vissa alternativa gräsmattor. Nedan visas två platser med lämpliga områden, som studerades mer detaljerat, med konkreta förslag på hur man designar alternativa gräsmattor i Holma. Både en inventering av den grön-grå relationen och en analys av lämpliga områden för att etablera alternativa gräsmattor behöver göras innan gestaltningsförslag tas fram (figur 91). Förslag på alternativa gräsmattor i Holma visas i figur 92–93.

Figur 92. Förslag till alternativ design för fläckvis torr och skadad konventionell gräsmatta belägen längs huvudentrén till Holma-kvarteret. Föreslagna ängar med "Cues to care" (tecken på omsorg) kommer att stärka platsens estetiska kvalitet och biologiska mångfald och stoppa fotgängarnas genvägar över gräset (design: J.Lööf Green, 2016).

Figur 93. Förslag till en alternativ design inom en av Holmas gångvägar bredvid husen. Denna smala gräsmatta används inte för någon fritidsaktivitet och kan därför omvandlas till en attraktiv, färgstark, svensk äng med flera klippta gångvägar (design: J.Lööf Green, 2016).

SLUTSATSER

De senaste trenderna inom omgestaltandet av konventionella gräsmattor, i världen och lokalt i Sverige, visar alla på en ganska tydlig tendens. Alternativa lösningar rör sig bort från den täta gräsdominerade gräsmattemodellen mot mer naturliga gräsmarker där gräs och örter kan växa tillsammans och bli en viktig resurs för människor och vilda djur och leverera viktiga ekosystemtjänster. Ängsliknande gräsmattor och annuella måleriska ängar är ganska enkla lösningar som redan används framgångsrikt i Sverige. För etablering av ängar i stadsdelar och parker anser vi att den mest effektiva metoden är att avlägsna den befintliga gräsmattan samt ca 10–15 cm av jorden och ersätta den med en magrare jord och sedan så ängsblandning på ytan. Trots att det här medför vissa initiala ekonomiska investeringar har det visat sig att dessa investeringar lönar sig senare, tack vare skötselvinsterna, då ängsliknande gräsmattor bara behöver klippas en gång per år.

När det gäller nya svenska versioner av ”grass-free/tapestry lawns” (örtgräsmattor) måste de studeras ytterligare med tanke på dynamik och blomningseffekt och möjligheterna att skapa en gräsmattelikande yta som skulle vara lämplig för rekreation.

Ändå kan örtgräsmattor definitivt användas redan nu för att demonstrera den biologiska mångfalden, till exempel i botaniska trädgårdar, kommunala parker och universitetsområden. Det mest effektiva sättet att etablera örtgräsmattor är med pluggplantor, vilket ger en stark blomningseffekt under det första året. Ett mer resurssparande och billigare sätt är sådd. Det första året måste då vägas in och annuella växter rekommenderas för att få en blomningseffekt.

Nästa steg i arbetet med örtgräsmattor bör vara att studera olika växtblandningar och hitta ännu fler effektiva kombinationer av lågväxande och tättväxande mattskapande örter som kan skapa estetiskt tilltalande ytor för olika rekreativa syften i stadsområden.

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Short communication

Lawn as a cultural and ecological phenomenon: A conceptual framework for transdisciplinary research

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ABSTRACT

Globalisation and urbanisation are driving the worldwide homogenisation of urban landscapes. The flora and fauna of cities in different parts of the world are very similar, irrespective of geography and climate. One of the most powerful symbols of modern urban landscapes is the lawn. There are just a few management options for urban lawns, regardless of how they are used and where in the city they are situated. Today, lawns occupy much of the green open spaces in cities (70–75%) and are located in private front and rear gardens, public parks, cemeteries, golf courses and along roads. Most people in the Western world view lawns as a 'natural' and even compulsory element of the urban landscape, without questioning their social, symbolic, ecological or aesthetic values. In this article we discuss the conceptual framework and methodological approaches being used in an ongoing transdisciplinary collaboration project including stakeholders to study lawns in Sweden as a social and ecological phenomenon. The overall aim is to understand the role of lawns in sustainable urban planning, design and management. The transdisciplinary approach allows us to exchange knowledge between scientific disciplines in order to influence the studies within each subject throughout the project and to achieve a multi-dimensional understanding of the lawn as a phenomenon. The involvement and close collaboration of stakeholders in the project allows us to obtain first-hand information on planning issues connected to lawns and existing planning data from cities and to focus on true implementation aspects rather than just theoretical recommendations.

Introduction

Globalisation and urbanisation are the major drivers of the worldwide homogenisation of urban landscapes. The flora and fauna of cities in different parts of the world are strikingly similar, despite geographical and climate differences (McKinney, 2006; Müller and Werner, 2010). In most of the Western world, urban landscapes have been influenced and shaped by the same landscape few architectural approaches, namely French formal, English Picturesque and Victorian Gardenesque and, in the 20th and 21st century, Modernism (Ignatieva, 2010). One of the most powerful symbols of these landscape architectural approaches, and thus of modern urban landscapes, is the lawn. Only a few management options have been adopted for urban lawns, regardless of how they are used and where in the city they are situated.

The use of lawns in our modern society is seen as a product of our life style (Giddens, 1990). Today, lawns cover a significant part of all green open spaces in cities (up to 70–75%). They can be found in private gardens and public parks, cemeteries, golf courses and along roads. Most people of the Western world view lawns as a 'natural' and even as compulsory element of the urban landscape, without questioning their social, ecological or aesthetic values (Stewart et al., 2009).

There is a common positive view of lawns as functional and accessible areas in parks, playgrounds and private gardens. Lawns often have symbolic value and people enjoy them (see, hear, smell etc.), although they may be not permitted to enter or use the lawn area. However, the intensive management practices used on lawns, such as frequent mowing and spraying of herbicides and fertilisers, has raised awareness about their potential negative impact on the urban environment. All previous research on urban biotopes has

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shown that lawns are strikingly similar in terms of plant species composition and, in their modern expression, are important contributors to the homogenisation of urban landscapes and loss of urban biodiversity (Ignatieva, 2011). Most grasses used for lawns are varieties originating from the same few nurseries or seed mixtures, creating habitats that have no equivalent within the native environment. In the US, 23% of the entire urban land area is estimated to be covered by lawns (Robbins and Birkenholtz, 2003), 62 000 t of pesticides are used by homeowners each year and 1.5 billion cubic metres of municipal water are used for irrigation of lawns each summer day. In Sweden too, lawns cover large areas of public courtyards, parks, golf courses, sports fields and traffic environments.

Like everywhere else in the Western world, lawns in Sweden are widely advertised by urban planners, landscape architects, developers and mass media as a very useful consumer product for the market. In the present project we regard lawns as specially constructed plant communities with a domination of a limited number of grass and herbaceous species which are densely planted and depend on a special management regime (regular mowing). The lawn is designed for social (sport and recreation), historical, aesthetical and cultural purposes (viewing, picnicking, playing golf and football, walking). There are intensively managed lawns (frequently cut short) which we call "conventional" and less-frequently cut lawns which are "meadow-like lawns". The latter lawns are closer to natural grassland in the sense that they are mowed and had bigger number of species. The environmental impact of lawns largely depends on the intensity of management (Cameron et al., 2012). If fertilisers, pesticides and herbicides are used, the surrounding surface water and groundwater may be affected. Bolund and Hunhamma (1999) present six major groups of important urban ecosystem services: air filtering, micro-climate regulation, noise reduction, rainwater drainage, sewage treatment and recreational/cultural values. Out of these six, the one where lawns are most important is the rainwater drainage. In vegetation-free cities, up to 60% of the rain water ends up as surface runoff. In areas with a permeable surface, such as a lawn, only 5–15% of the rain water becomes surface runoff, whereas the rest evaporates or infiltrates into the ground providing important soil-moisture for trees and other vegetation that further contributes to many of the abovementioned ecosystem services.

Although lawns may have positive effects on the environment, e.g. through carbon sequestration in soil (Qian et al., 2010; Zirkle et al., 2011), the total effect on the environment may be negated by the frequent use of mowers powered by fossil fuels. Lawns in general could also serve as a habitat for grassland fauna, including bees and butterflies that utilise urban environments (Ahrné et al., 2009; Ockinger et al., 2009; Matteson and Langellotto, 2010). Despite the important role of lawns in the urban landscape, there are few comprehensive studies including their social, ecological, cultural, historical and symbolic values, as well as their management and overall environmental impact. Most existing studies have been conducted in Europe, the US and New Zealand, where lawns are causing problems with invasive species because most lawn grasses originate from Europe (Müller, 1990a,b; Thompson et al., 2004; Stewart et al., 2009). In urban planning and policy documents, the emphasis is often placed on sustainable planning and the importance of promoting ecosystem services, but since these scopes are inherently complex, they are difficult to implement in practice. In order to provide urban planners with valuable information on how this could be achieved, one way could be to focus on a major urban green element, for example lawn, and study it from different scientific perspectives in collaboration with practitioners. However, this calls for interdisciplinary projects.

Transdisciplinary research on lawns

Here, we describe the conceptual framework and methodological approaches of an ongoing project on lawns (Tress et al., 2003). The project is a transdisciplinary collaboration including stakeholders. The main research question "What is the phenomenon of lawn in Sweden?" involves studying lawns from different perspectives. The overall aim is to understand the role of lawns in sustainable urban planning, design and management. Ecological knowledge, social values and norms influence the management of urban green areas (Andersson et al., 2007) and may thus influence their biodiversity, environmental impact and the ecosystem services they provide. Without understanding the social motives behind the strong attachment of modern Western society to lawns, introducing potential alternative solutions and changing conventional management routines can be difficult. The transdisciplinary approach allows us to exchange knowledge between scientific disciplines in order to influence the studies within each subject throughout the project and to achieve a multi-dimensional understanding of the lawn as a phenomenon. The involvement and close collaboration of stakeholders in the project allows us to get first-hand information on planning obstacles relating to lawns and existing planning data from cities, and to focus on true implementation aspects and not just theoretical recommendations.

To frame the project, we are using a multiscale approach and studying lawns from different perspectives: from the large scale including the entire city (estimating the total coverage of lawn as a land use type) through the medium neighbourhood level (providing typology, coverage of lawns, their functions, values and use in parks or backyards) to the fine level of the lawn itself, with emphasis on biotope characteristics such as biodiversity and carbon sequestration. The study areas were chosen within dominant typologies of neighbourhood areas in Sweden, multi-storey housing areas and residential private houses. The pioneering character of our research is emphasised by the broad perspective, including qualitative studies of social, cultural and historical values and a number of classical quantitative biological studies (biodiversity of plants, pollinators and decomposers, and carbon balance), as well as design considerations. All these aspects are being synthesised to assess the environmental impact of lawns and their importance for ecosystem services in three Swedish cities. Another very important part of this interdisciplinary research project is the involvement of urban planning and design dimensions, with practical output for practitioners and decision makers who are formulating and implementing municipal policies.

More specifically, the aim of the project is to obtain interdisciplinary quantitative and qualitative data on lawns which will allow us to estimate the values of different lawns and draw conclusions about their negative and positive environmental impacts in our modern cities. Our ambition is not to avoid or prohibit lawn as a phenomenon, but to critically analyse it, connect it to people's needs and suggest a new planning, design and management paradigm.

Specific objectives of the project are:

- To classify and identify main types of lawns and their current management practices.
- To estimate the proportion of lawns related to other green and blue areas in the city, such as forests, agricultural land and water bodies.
- To understand the motives for decisions about the establishment and management of lawns among different stakeholders.
- To examine historical and social roots, perceptions, norms and aesthetic, symbolic and design values of current management practices of lawns.

- To understand the role of lawns in urban hydrology and water management.
- To analyse the environmental impact (energy use and carbon footprint) and biodiversity (plants, bumblebees, butterflies and earthworms) of lawns.
- To identify how to establish and manage lawns so as to promote their provision of ecosystem services in cities (e.g. pollination), while simultaneously reducing their environmental impact and addressing people's needs.
- To study how different human interests and values interact (or conflict) from a management perspective and how to find sustainable planning and design solutions.

We will deliver the results directly to stakeholders by providing an urban greening manual, demonstration sites and different management packages for municipalities and communities with recommendations on how to design, establish and manage sustainable lawns.

Research framework and methodology

We aimed to have a spatial overlap in choice of sites among research disciplines, but at the same time to create a model that can be relevant for answering questions within different fields (Fig. 1). The first few months were specifically dedicated by participants to creating an understanding of each other's disciplines and perspectives. Another important part of the approach was to establish stakeholder and focus groups involving local municipality experts. A special role was given to a scientific focus group that consisted of leading international and local experts on lawns, including an expert in plant–pollinator interactions, a horticultural scientist, an expert in grass-free lawn and a sociologist. We also involved non-academic participants such as different stakeholders in the project.

The *quantitative* methods used in natural sciences with replicate samples and reproducible research layouts are also being combined with *quantitative and qualitative* methods employed in social science, using interviews and surveys based on estimations and stakeholder values. These in turn are being combined with *case study methods* used in planning science, where unique cases are studied with method triangulation for validating the results (Yin, 2013).

The process of choosing the case studies for field work was directly correlated with three historical and cultural peculiarities that dominate Swedish urban planning structure. Multi-family residential housing neighbourhoods with significant amounts of lawn area are the most common typology in Swedish cities. We also included a category of Swedish private houses (detached housing with private gardens). There are about 2 million such detached houses in Sweden, making private houseowners an important stakeholder group with potentially a wide range of views and motives for planning, nurturing and maintaining their private lawns (Lundgren, 2001; Berg, 2004).

We chose three case study cities, situated in the south (Malmö, 280 000 inhabitants), east (Gothenburg, 530 000 inhabitants) and west (Uppsala, 200 000 inhabitants) of Sweden, in order to cover differences in climate conditions and local culture. Within each city, three types of lawns were identified for study: (1) residential lawns in private (detached house) gardens; (2) utility lawns (common conventional, frequently mowed lawns); and (3) meadow-like lawns in multi-family residential housing areas (cut only a few times a year). Utility (conventional) and meadow-like lawns are two main classes differing in management intensity that have been adopted by all Swedish municipalities. The classification of lawns is mostly based on the management intensity (including frequency of cutting, using herbicides and pesticides). Usually there is also one more type of lawns, the parterre lawn, which has the highest management intensity. Parterre lawns are uncommon in Sweden. Instead we included golf courses with lawn types ranging from very intensively managed tees and greens, to fairways with intermediate management intensity and roughs with the lowest management intensity. Golf courses are also included because of their more intensive use of purchased inputs, and because of their potential for more sustainable management by providing habitats for grassland species (Colding and Folke, 2009).

For calculating the percentage of the lawn coverage in the case study cities, we decided to use existing data obtained by LiDAR (Light Detection And Ranging), a remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light, complemented with stakeholder knowledge of current managed areas.

As carbon balance studies are labour-intensive, we decided to limit our detailed research to three lawn types differing in management intensity (utility and meadow-like lawns in multi-storey residential areas and golf courses). We researched only 'mature' lawns, i.e. at least 10 years old.

Methodological approach

Social, cultural and historical research

In view of the complexity and novelty of this transdisciplinary research project, during the first year we carried out a pilot study to test the suggested methodology and to establish contacts with keynote stakeholders. For the social, cultural and historical research, we looked at the origin and history of lawns worldwide and particularly in Sweden (we visited sites of alternative lawns in Europe), motives behind management and establishment of different types of lawns, characteristics of Swedish lawns and the perception among people of different types of lawns, the origin of seed mixes and the peculiarities of planning, design and management practices for lawns. The methodology included: (1) A literature review and archive survey; (2) questionnaires on management and choice of plant material, targeting stakeholders (who plan and manage the specific lawns), people living in multifamily houses and golf players; (3) interviews with private gardeners, public planners, decision makers, politicians, landscape architects and horticulturalists to obtain information concerning their vision, planning, management and perception of lawns; (4) observational studies on how frequently and for what activities the selected lawns are utilised; and (5) surveys: short interviews with lawn visitors to get an idea of how lawns are perceived and utilised. In the social science part of the study we also integrated some questions from other teams. One of the most challenging parts of the methodology was to put together and integrate different studies (sub-projects).

Biodiversity and environmental impact

Biodiversity and environmental impacts of differently managed lawns being studied are species diversity and composition of plants, bees, butterflies and earthworms, energy use and carbon footprint. Carbon sequestration is being modelled, as is the balance between sequestration and emission of greenhouse gases (GHG), including hidden carbon costs (GHG emissions associated with production of mineral fertilisers, pesticides, mowing etc.) in the different lawn types.

Within each of the three cities, we surveyed three replicates of each of the public lawn types (utility and meadow-like lawns) in six multi-storey housing areas. We also surveyed three management types (fairway, rough and high rough) at six holes in two golf courses per city. At all study sites, all species of vascular plants

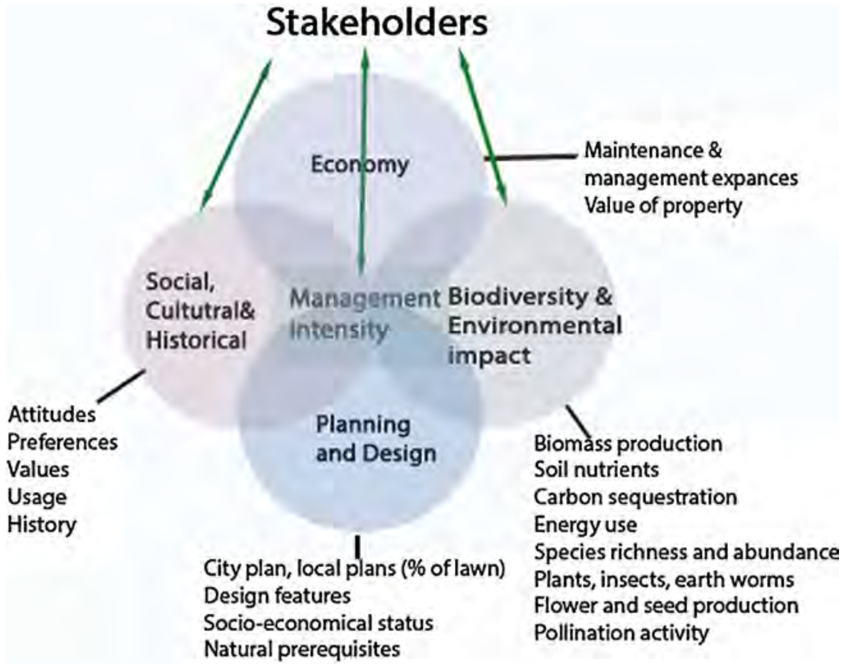

Fig. 1. Components of the transdisciplinary project on lawns. The four main areas overlap greatly in terms of research questions, interactions and, spatially, field sampling.

were recorded (vegetative cover and counts of reproductive parts) within small plots (0.5 m × 0.5 m). We also recorded the amount of flowers or fruits produced, as this is important for the connection between plants and pollinators. Species richness and abundance of bumblebees and butterflies, as well as number of flowers visited by the pollinators, were noted in larger plots (3 m × 3 m). In these plots we also estimated total number of flowers. The survey of all plots and points was conducted on two occasions during the flying season to include plants with different flowering periods and pollinators with different flight periods. We focused on the grass surface, but also estimated the availability of flowering plants within a larger distance from the inventory plots, e.g. in flowerbeds. Since the organisms studied may also be influenced by the surrounding urban landscape, we included GIS analyses of the landscape at a larger scale, examining landscape composition and connectivity among grasslands.

Soils were sampled and organic carbon and nitrogen concentrations, soil bulk density and roots determined. Carbon sequestration is calculated using the Introductory Carbon Balance Model (ICBM model) (Andrén and Kätterer, 1997). Input to the model is the lawn biomass production and climate data (temperature and precipitation). Above-ground lawn biomass is determined through manual cutting of sub-plots within each of the two lawn types and the golf courses. The cutting frequency mimics the management practice used on the particular lawn type. Root biomass production estimation is based on shoot/root ratios obtained in earlier calibrations of the ICBM model (Kätterer et al., 2011), as are other model parameters such as stabilisation coefficient and rate constants for degradation.

The energy use and emissions of GHG are being assessed in a life cycle perspective, i.e. including all relevant activities in the management chain, from production of e.g. purchased inputs to disposal according to a standardised ISO procedure. The energy use related to the management of different lawn types such as irrigation, mowing and fertilization is being investigated through interviews and questionnaire surveys of stakeholders, combined with a literature search, and divided into different energy sources. In addition to CO_2 emissions related to the management, nitrous oxide emissions both from production of nitrogen mineral fertiliser and soil are estimated and carbon sequestration is modelled using the ICBM model. Earthworms are important for soil conditions and soil fertility and are being sampled in Uppsala using the mustard extraction technique at all biodiversity sites (Pelosi et al., 2009).

Alternative design

In the first year we established a demonstration trail representing different experimental sites of alternative lawns at Ultuna Campus, Uppsala, as an important educational facility for academics as well as public communities. For example, these sites contain plant communities suitable for bumblebees and butterflies, as well as meadow plants suited for wet and dry conditions. This work relies heavily on active participation and consultation within the focus and stakeholder groups and is based on exchange of scientific and practical information from leading European scientists and Swedish practitioners working with sustainable lawns.

The final year of the project is intended for critical evaluation of existing design, establishment and management practices of conventional lawns in Swedish cities and their economic, social and environmental effectiveness. We have also decided to analyse existing European sustainable alternatives to conventional lawns, such as meadow lawns (established from biodiverse mixtures (up to 25–30 species of different grass and herbaceous species), grass-free lawns (made by using specific mowing tolerant plants instead of grass, (Smith and Fellowes, 2014) and pictorial lawns (made from annual decorative plants) (Hitchmough, 2009) and their appropriateness of using in Swedish cities. The economic and environmental benefits of such alternative lawns have been actively discussed in recent years. The final stage of this project will result in suggestions of different practical design solutions for planning, design and establishment techniques as well as management schemes for different types of lawns in all three case study cities. We are not necessarily against the conventional lawns but call for critical evaluation and suggestion of wiser resource use in the urban environment.

Initial results and implications for future research

The involvement of different disciplines and of stakeholders is the strength of this project, but also makes it complex. It took time and a lot of effort in the beginning to understand how to combine the methodologies from different disciplines and adapt them to collective goals and objectives. Series of joint meetings, reading each other's articles, collecting background information, building networks and creating a database of local contacts were essential starting points for the project. Stakeholder and focus group meetings identified an urgent need for lawn research. All municipal managers are very supportive as well because they understand the necessity of changing the current costly and unsustainable management paradigm. However, due to the complex character of Swedish home ownership and management practice (many owners and contractors are involved in maintenance and management), the process of obtaining data was not an easy task and took a longer time than expected.

The pilot study in the first year worked well and by the end of first season the methodological approaches in all packages had been adjusted and in some cases significantly changed. For example, we found out that in a large city such as Gothenburg, it would be very time-consuming (costly) to manually interpret the coverage of all lawns using orthophotos. In the pilot study we tried to use normalised difference vegetation index (NDVI) and infra-red-spectra to estimate the area of grass in Gothenburg. However, we found that the NDVI was not capable of capturing vegetation in shaded areas and it was also difficult to distinguish grass from trees and other vegetation, thus making it less usable. Moreover, not all cities have red spectra in their aerial photos. Using existing LiDAR data proved to be the best method of estimating total grassland cover. In Sweden there is national coverage of LiDAR data, and in addition some cities (e.g. Gothenburg and Uppsala) have their own LiDAR with higher resolution. We used the municipal management maps of grasslands as references when interpreting the intensity in the LiDAR data.

In the social survey, the questionnaires for lawn visitors and managers/politicians were changed several times until they were worked effectively. Establishment of a website and demonstration trail were effective visualisation and popularisation tools and attracted the attention of stakeholders and the public at large. Some municipalities would like to establish new larger demonstration sites in botanic or community gardens.

Working with an interdisciplinary approach initially needed numerous physical meetings (as well as reading of selected articles from each of the disciplines) to understand the intentions of other participants for the project, identify possible synergies and be able to cooperate. It was also important to understand that in such projects aiming at both a broader and a detailed perspective, there will be compromises within each of the scientific subjects and they might not be able to perform as detailed studies as they would like.

For the success of the research aim to use the knowledge gained in the project and implement it on the ground, it is crucial to have close collaboration with stakeholders and let them be part of the research planning process. Only informing stakeholders about main results in a fact sheet or a scientific paper is not sufficient if sustainable development is to be implemented: closer meetings and mutual understanding during the scientific process are necessary. We plan to continue working closely with stakeholders. Our final goal is to influence and even change the attitude towards lawns among professionals and the public.

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The lawn as a social and cultural phenomenon in Sweden

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ABSTRACT

Lawns have a significant influence on the cityscape as one of the essential elements of green spaces and an important part of people's everyday lives. Most people in the Western world view lawns as a compulsory element of the urban landscape, almost an icon, without questioning their social, symbolic, ecological or aesthetic values. This research is a part of the conceptual framework and methodological approaches that are being used in an ongoing transdisciplinary collaboration project to study lawns in Sweden as a social and ecological phenomenon.

The overall aim of this study was to investigate social and cultural perceptions of lawns, as well as motives behind decisions about the establishment and management of lawns in Sweden. Two multi-family housing typologies, the 'Million Programme' and 'People's Homes', were examined due to their dominance in Swedish cities. We also studied how an alternative vision of conventional lawns can be applied and accepted by urban residents. We estimated lawn cover in multi-family housing areas and links to people's perception and use of lawns. Questionnaires, semi-structured interviews and observational studies were used (N = 300). Our results showed that people like lawns even if they do not always directly use them. Lawns cover the most significant amount of outdoor spaces in all multi-family residential areas and accompany people everywhere from the house to the schoolyard or park. The total lawn cover in the study areas was 27.8%. Lawns were particularly valued as important places for different outdoor activities (playing, resting, picnicking, walking, socialising) and enjoying the green colour. However people do not want to use a vast monotonous lawn, but a variety of spaces that provide good conditions for different senses (sound, smell, touch and sight) and activities. Alternative lawns were also appreciated by many citizens, politicians, planners and managers. The implementation of new types of lawns requires special planning and design solutions adjusted for each particular neighbourhood.

1. Introduction

Lawns occupy a significant proportion of green spaces in many cities worldwide today (Stewart et al., 2009). According to the most recent EU study "Green Surge – A typology of urban green spaces, ecosystem provisioning services and demands" (Braquinho et al., 2015), green spaces are defined as "any vegetated areas found in the urban environment, including parks, forests, open spaces, lawns, residential gardens, or street trees". In 44 identified types of urban green areas, the lawn is one of the most common elements, for example in large urban parks, botanical and zoological gardens, historic parks/gardens, institutional green spaces, green playground/school grounds, street green or green verges and house gardens. The complex character of urban green areas is well recognised and there is a growing body of research investigating the roles of green spaces in social, economic, cultural and environmental aspects of sustainable development (Haq, 2011). Even if lawns are one of the most dominant elements in green areas in all countries (irrespective of climatic differences), this phenomenon itself is not well researched, and especially not its socio-cultural component. At a time of climate change and the search for a sustainable urban environment, there is an urgent need to have interdisciplinary empirical quantitative and qualitative studies on lawns: the values of different lawns are revealed and conclusions drawn about their negative and/or positive environmental impact (Ignatieva et al., 2015).

There are many different definitions of 'lawn', but we define it here as an artificially created or modified plant community (phytosociological composition) consisting predominantly of grass (more technically graminoids), but it may have spontaneously occurring herbaceous species (which are also called 'lawn weeds'). Lawns are used for recreation and sports, and as a pleasant green backdrop for displaying other plants or functional (playgrounds)

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and decorative elements (pieces of art, fountains, benches and pavilions). One of the main characteristics of lawns is their construction technique (preparation of soil and seed mixtures) and management regime (mowing, herbiciding, fertilising, watering) aimed at maintaining grass species, controlling weeds and mosses, and keeping a certain grass height.

The lawn is quite a recent ecological and cultural phenomenon. Lawns are an artificially created grass-dominated plant community designed mostly for pleasure and/or decorative purposes. It most probably appeared in medieval times in Europe (Fort, 2000; Ignatieva, 2011). A broader use of lawns is connected to the development of the most influential landscape architectural styles, such as picturesque and gardenesque (18th –19th centuries), in Europe, the US, Australia and New Zealand. The 20th century Modernism movement used lawns as a massive prefabricated element in all green areas (public and private). Lawns today are seen as a symbol of globalisation and the market economy (Ignatieva, 2010).

An ecological component assessment of lawns (floristical and phytosociological composition, urban biotope) has been a primary subject in lawn research since the 1990s in Germany (Müller, 1990) and later in England (Thompson et al., 2004), New Zealand (Ignatieva et al., 2000; Stewart et al., 2009) and recently in other countries (Bertocini et al., 2012; Pooya et al., 2013).

The US and UK are trying to raise awareness of broad-scale research – an estimation of lawn cover in cities (Milesi et al., 2005; Gaston et al., 2005; Edmondson et al., 2014) because of the dominant role of lawns in suburban private gardens and public green spaces. For example, the combined area of lawn (turfgrass) represents an estimated 23% of urban land cover in the USA (Robbins and Birkenholz, 2003). In the early 1990s the area cultivated with lawns in the US was up to three times greater than that of irrigated corn crops. Awareness of the environmental impact of intensively managed lawns in US suburbia resulted in a rising number of scientific and popular publications on the history of American and English lawns and an analysis of socio-cultural and even anthropogenic reasons (speculation that people love lawns because of the evolution of humans in savanna-like landscapes in East Africa) behind an obsession for the perfect short-cut green lawn in modern society (Schultz, 1999; Teyssot, 1999; Fort, 2000; Macinnis, 2009). In recent years, particularly in the US, England and Germany, there is a growing number of papers discussing the 'evils' of modern monotonous and homogenous lawns and the need for alternative sustainable solutions as well as the education of local citizens in favour of a new vision of lawns in urban nature (Borman et al., 2001; Pollan, 1991).

The social norms and psychological and social predictors of lawn fertiliser application have been studied in the private gardens of American suburbia (Kaufman and Lohr, 2002; Carrico et al., 2012). However, there are still very few proper empirical social studies on perceptions, norms and aesthetic values of current use and management practices of lawns, especially in non-American countries.

Swedish cities share the same lawn pattern as many other cities around the world. Lawns are widely advertised by urban planners, landscape architects, developers and mass media as a very useful consumer product for the market. It is the dominant component of green areas in multi-family housing, public parks and gardens, street verges and cemeteries as well as in private gardens and on golf courses. However, no studies of the biodiversity, environmental impact or public use of lawns, for example, have been conducted in Sweden (Ignatieva et al., 2015).

The overall aim of this study was to investigate social visions and perceptions of lawns and motives for decisions about the establishment and management of lawns in common housing areas in Swedish cities. The main research question involved studying lawns from different perspectives. This also included an examination of how sustainable (alternative) design and management of lawns could be applied and accepted by urban residents, an estimation of lawn cover in typical multi-family housing areas, and people's perception and use of lawns. Without understanding the social motives behind the strong attachment of modern western society (including Sweden) to lawns, it is impossible to introduce potential alternative solutions and change conventional management routines. The transdisciplinary approach (in this particular case between data on lawn cover in Swedish residential areas and visions of lawns by local residents) allows us to exchange knowledge between scientific disciplines and achieve a multidimensional understanding of the lawn as a phenomenon.

2. Lawns in Sweden

The history of lawn establishment in Sweden is similar to that in many other European countries. Grazed meadows have existed for millennia and during the Iron Age it became possible to harvest hay in larger amounts. It is difficult to say exactly when grass-dominated plots (lawns) for entirely decorative purposes appeared in European gardens, including Sweden (Ignatieva and Ahrné, 2013). In Medieval European gardens of the 12th–15th century, cut turf from meadows with their various grass and herbaceous flowering plants was used in monastery (and castle) gardens. Lawns were first used in Sweden as entirely decorative short-cut grass areas during Renaissance and Baroque times (1600–1750s). The establishment and maintenance of lawns was expensive and resource-consuming and lawns were initially used only in limited amounts as a parterre element or *tapis vert* (green carpet) in the grand parks of royalty and the nobility. During the English landscape park era (1750s–1840s), rather large undulating lawns were still the prerogative of the nobles. Public parks first emerged in the second part of 19th century, marking a new era of Swedish lawns. They started to be an important decorative and recreational element and served the needs of the common people rather than those of the privileged higher social classes. Swedish parks at that time were valued as places for good health and 'moral education'. They provided a pleasant environment for strengthening the family' by taking people's minds away from drinking and gambling (Wärn, 2013).

From the second part of the 19th century, the process of transformation of an agrarian country to a highly industrialised nation began, resulting in accelerated urbanisation. After the Second World War, Sweden's undamaged industry needed even more urban labour to produce goods for the destroyed Europe. New urban development plans and a new generation of housing areas with apartment blocks were built all over Sweden. The planning structure of Swedish cities before and after the war directly reflected the economic and political situation and were connected to the "Swedish Model" implemented by the Social Democratic Party (in power from 1932 to 1976) with the aim of creating a more equal society. This policy resulted in creating the progressive welfare state. One concrete goal was to provide simple, but good-standard apartments and healthy outdoor environments for the working class (Dahlberg, 1985). Influences also came from the international functionalism movement, strongly expressed in the Stockholm Exhibition in 1930. The basic idea was that form or design should follow the function of dwelling both indoors and outdoors in new housing areas. Functionalistic planning and architectural values and policies included equal access to high-quality public spaces and provision of sun, light and air and an improvement in the population's health. As a result, functionalistic multi-family housing areas – "People's Homes" (*Folkhemshusen*) in 1940–1959 and the "Million Programme" (*Miljonprogrammet*) in 1960 until the mid-1970s – were established all over Sweden. 500,000 apartments were built in 15 years during the People's Home programme and

Fig. 1. The People's Homes area of Tunabackar in Uppsala, with bright lush inner courtyards covered by large public lawns. (Photo: Per G Berg).

900,000 homes in 10 years for a nation with a population of seven million. In both forms of housing, lawns cover large areas. Following the ideological and social goals of providing a cheap and functional space, lawns were seen as an excellent outdoor element for play, walking and recreation. Lawns were a standard element that fitted well into functionalistic aesthetics of a simplified, rationalistic (prefabricated) style with limited variation in design schemes.

2.1. People's Homes and the Million Programme

The People's Homes project originally consisted of mostly rented apartments in three-storey houses in natural settings or in closed blocks around lush inner courtyards (Fig. 1). Lawns were initially used to cover large spaces next to the houses because of their simple and cheap maintenance.

Green resources then became common in courtyards, with a plethora of garden rooms, large trees, pergolas, lush playgrounds and appropriated ground-floor gardens. The initial idea for the lawns was to constitute the green floor of the individual courtyards and the core of larger common green parks (Persson and Persson, 1995). In many cases, lawns were built on former agricultural or meadow land. Playgrounds, flower beds, pathways, street furniture, gravel ball parks, shallow paddling pools and, in later decades, picnic places were all surrounded by lawns.

During the Million Programme most houses were initially low-rise, but later comprised larger-scale high-rise areas. The strongest green-blue infrastructure values for these areas were considered to be their closeness to nature in the periphery (urban fringe) of the city. Forest patches and larger lawn areas were suggested as an asset in the Million Programme as well, but the courtyards between buildings had only small patches of lawn. Larger lawn areas were therefore established in large-scale residential parks and adjacent groves, meadows and garden plots. The weakest expression of green planning in the Million Programme was inner courtyards planted with exotic standard plant material (*Berberis* and *Dasiphora*) growing on very thin topsoil within monotonous lawn areas.

3. Methodology

3.1. Case studies

Our research was conducted in three case-study cities (Göteborg, Malmö, Uppsala, see Fig. 2) in 2013–2016. Göteborg, on the south-west coast, is the second largest city in Sweden, with a population of 533,000 (1 January 2015). The topography, with rough, barren rocky outcrops and cliffs, has influenced the city's spatial development. Malmö is the third largest city in Sweden, with a population of about 319,000 (1 January 2015). Unlike Göteborg with its hilly landscape and remnants of natural vegetation, Malmö has plain topography and many of Malmö's neighbourhoods have artificial turfed green hills to fill this topographical 'gap'. Uppsala is the

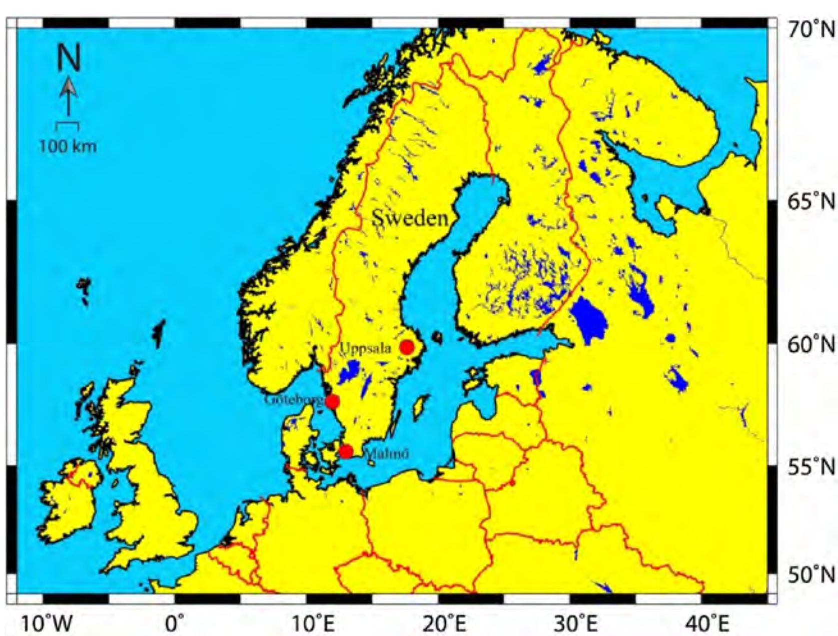

Fig. 2. Location of the case study cities in Sweden.

Fig. 3. The Million Programme area Eriksbo (1967–1971) in Angered, Göteborg. Light green is lawn (and small amount of meadows or sports lawn) and dark green is trees, shrubs and an all-weather soccer pitch. The reddish and whitish blocks are roofs and the grey is roads or parking lots. Houses and outdoor spaces were renovated and partly rebuilt in 1985–1990.

fourth largest city in Sweden, with a population of around 207,000 (1 January 2015). The city has many remnants of forests, which have mostly been transformed into accessible recreational spaces. The city covers 48.8 km^2, of which 10.5 km^2 are covered by natural plant communities (Park plan for Uppsala City, 2013).

The cases in each city were strategically selected from well-researched (Berg, 2004; Berg et al., 2010) dominant townscape types (Million Programme and People's Homes areas) representing ordinary housing (Johansson, 1991; Reppen et al., 2012) for up to a third of the Swedish population – areas where lawns inside and adjacent to housing areas are still dominant elements in the green spaces (Persson and Persson 1995). The cities represent some of Sweden's major urban regions, but in various landscape settings in different parts of Sweden.

In each city, we studied one People's Homes area and two Million Programme areas: Kyrkbyn, Eriksbo and Angered in Göteborg, Augustenborg, Holma and Rosengård in Malmö and Tunabackar, Gottsunda and Eriksberg in Uppsala. These particular neighbourhoods were selected based on consultations with stakeholders from municipalities involved in the LAWN transdisciplinary project who had pronounced interest of knowing more about these areas in particular. Downtown and industrial areas of the cities were not included in the analysis.

3.2. Types of lawns

There are two types of lawns officially identified by Swedish municipalities (Hellener and Vilkénas, 2014). The majority are 'conventional' lawns, which are cut at least 10 times per season to a height of 4–10 cm according to official municipal definitions (Andersson and Bergbrant, 2015). The other type is "meadow-like" lawns, which are cut once or twice per season. Meadow-like lawns currently cover only a tiny area and are mostly located next to remnant natural vegetation on the outskirts of neighbourhoods or within public parks. There are also sports lawns, such as football fields, which are often more intensively managed. They represent a small proportion of the total urban lawns.

To estimate lawn cover we used aerial photos and ArcMap background data from May 2015 for manual mapping. The outer border of each specific housing type was strategically chosen, which affected lawn cover, since it was estimated by dividing area of lawn by total area. The outer borders of People's Homes were easy to detect, while the borders of the Million Programme housing areas were more difficult to define as these areas often lie on the urban fringe of cities adjacent to nature, making the borders less distinct. Furthermore, vast green areas are present in the surroundings and it is difficult to see whether these belong to the housing areas or the surrounding landscape (Fig. 3). In each location, the total area of lawn, meadow, sports lawn, trees, shrubs, gravel (mainly all-weather sports pitches), bare rock (rocky outcrop, very common in Göteborg), bare soil, water and agricultural fields was mapped (Fig. 3). Roads, parking lots and dwellings were not included (but were indirectly estimated when everything else was removed).

For the social part of this study of lawns, we used questionnaires, semi-structured interviews and observational studies (Sjoberg and Nett, 1968) at 10 sites in the case-study neighbourhoods in our three cities. Our focus was particularly on lawns and the specific qualities provided by lawns. Lawns are the dominant element of green areas in all the researched neighbourhoods. Green areas here consist of lawns with scattered groups of shrubs and trees, with the intrusion of flowerbeds and playgrounds. Designed pedestrian paths and cycle ways were also typically surrounded by lawns.

We started our research with a pilot study in 2013 in Uppsala and tested the questionnaire. Ten questions were related directly to the main research questions on lawns (perception, expectations, use of lawns, their management and attitudes towards using some alternatives to conventional lawns with more biodiverse and less resource-intensive options) and the last question (11) aimed to connect lawns as a phenomenon to the wider context of green area qualities (Table 1). We asked randomly selected people (who were passing by or sitting on lawns, playing, sunbathing or relaxing, or sitting on the benches next to lawns) to answer questions (Somekh and Lewin, 2005). We tried to cover people of different cultural and ethnic backgrounds, ages and genders. Before starting the interview, we asked people whether or not they lived in the vicinity of the site. Interviews were performed in the late spring and summer months (due to the nature of the Swedish climate and use of lawns) on weekdays and at the weekends, at different times of day (morning, afternoons, late afternoons), aiming to cover as many categories of local residents as possible. We also asked the respondents

Table 1
Questions on social activities in housing areas.

1	How do you perceive the value of having access to a lawn/grass areas in your neighbourhood?
2	Are there lawns here or nearby that you usually visit? If yes, then which one/ones?
3	What do you think about the maintenance of grass areas in your neighbourhood in general?
4	What do you think about lawns that are cut only 1–2 times per year (for example meadow-like lawns)?
5	What do you think about alternative lawns (such as flower-rich lawns, meadows with perennials or annual pictorial meadows?
6	If you could decide, how would you like to design grass areas in your neighbourhood?
7	How would you rate the following statements regarding the grass area in this neighbourhood (rating from 1-disagree to 5-agree): well maintained, safe place for children and adults, beautiful and friendly place, suitable for leisure activities, a great place for rest and recreation, an important place for socialising with neighbours and friends?
8	Do you think that lawns generally create a good habitat for living creatures, such as insects, birds and mammals?
9	How often do you use lawns for different purposes (rating from 1-disagree to 5-agree): exercise/sports, sit/rest, social activities with neighbours/friends/family (party, meal, barbeque *etc.*), to get to other areas (shortcut), to experience nature, to look at (aesthetic value), other?
10	In which season do you use lawns most?
11	Is there anything you would like to add concerning lawns and green areas?

how long they had lived in the neighbourhood, their occupation and their type of household (single or family with children). All answers were written down by the interviewers on printed questionnaires. At each of the 10 sites, we conducted 30 interviews with residents (300 interviews in total).

The field data collection was based on the principles that 50% of the respondents in the six sites should be female and 50% male. We aimed to have 30 respondents at each site who were equally spread among the following age categories (15–24, 25–50, 51–65 and 66+). People were asked to answer questions related to alternative lawns, illustrated by pictures (such as flower-rich/grass-free) lawns with low-growing herbaceous plants, meadows with perennials that are framed by conventional short-cut lawns, or meadows with annuals (pictorial meadow) (Fig. 4).

Observation studies were carried out in places where we could observe people's movements. At each site, we conducted observation studies in three different spots. We recorded activities and their frequency for 10 min on selected days in June, July and August. Data were collected by using a pre-coded schedule in which different kinds of activities were listed, such as walking/passing through, walking with a dog, cycling, picnicking (and social gathering), playing, sitting and exercising (Whyte, 1984). We also wrote additional notes about how long people stayed in each site and if they were alone or in company. We also recorded weather conditions (sunny, cloudy, rainy, cold, and warm). The aim was to discern and identify usage patterns linked to the character of lawns in the different case study sites.

Politicians, municipality managers, city planners, landscape architects and property managers were interviewed about policies, lawn management and biodiversity (a total of 23 interviews). We also asked about their level of education, their responsibility in the particular municipality, plans and resources (budget, staff availability etc.) for lawn management, their understanding of lawns and their role in modern green areas, and the opportunities for environmentally-friendly lawns and the presence of wildlife, such as bees and butterflies. Furthermore, we sought to determine the 'perfect' lawn from the stakeholders' point of view. The qualitative data from interviews were analysed by: 1) sorting the data into themes and codes, 2) counting the number of occurrences of the themes and codes, and 3) selecting statements that were representative of the majority and minority of interviewees.

4. Results

4.1. Lawn cover

In all our case studies lawns occupied quite significant areas. The total lawn cover ranged between 17.7% and 47.7% (average 27.8%) in the multi-family areas (both Million Programme and People's Homes) (Fig. 5). The Million Programme areas in all cities had on average 24.8% lawn (lawns, meadows and sports areas), 18.7% forest and shrubs and 49.9% infrastructure. The People's Homes areas had on average 33.1% lawn, 12.4% forest and shrubs and 54.4% infrastructure.

*Sport lawns were not considered in the social study but mapped as one of the lawn types existing in cities.

4.2. Social study

We succeeded in obtaining the planned balance (50% male and 50% female) and age distribution in all six case studies. Since humans often have a complex personality and different lifestyles they need different spaces for different activities depending on the weather, time of the day and even individual moods at a particular moment.

We could not find any specific patterns between the answers of males and females in our data. In all three cities, people appreciated lawns in their residential areas and surroundings. There was no significant difference depending on age, but there was a tendency for younger (5–15 years) and elderly people (65+) to have more opinions and expectations concerning lawns and also the green outdoor environment. The majority (more than 70%) of the youngest and eldest respondents in our study who commented on lawns also had many opinions about how lawns could be more attractive.

Households with small children also had many suggestions about how lawns and the green spaces between buildings could be used much more efficiently. Households with middle-aged people (who have full-time work) and who had no children or older children (that mainly stay at home) did not, in most of the cases, mention anything specific that they would like to change. They seemed to be satisfied with the existing conditions of lawns. Parents of small children and the elderly often stressed the importance of accessibility, closeness and functionality of playgrounds, benches and other elements located on lawns. People from all kind of households mentioned the importance of having an extra "outdoor space" close to home.

One of the very first impressions in the study was very good familiarity with local lawn areas among respondents. People were actually even surprised to be asked about lawns, since all their life it has been one of the most familiar and commonly seen elements of their outdoor environment. The lawn cover estimate for each neighbourhood studied corresponded with our social data reporting that lawns surround residents everywhere. As one of Kyrkbyn's residents said: "I see it as a given element. I would miss lawns if they were not here". Respondents often associated lawns with summer and most lawns were designed for summer activities.

When we asked about the value of having access to lawns in outdoor spaces, the majority of interviewees responded that such access is "very valuable" and "very important". One resident said that lawns "become more important as you get older" and are "especially important for those who have no opportunity to go to other green places outside their house". Lawns seem to be appreciated for their aesthetic value, even if they are not directly used for

Fig. 4. Three alternative options for lawns presented to respondents that were linked to question 5 in Table 1. (Pictures: J. Vilkenas and A. Helner, 2014).

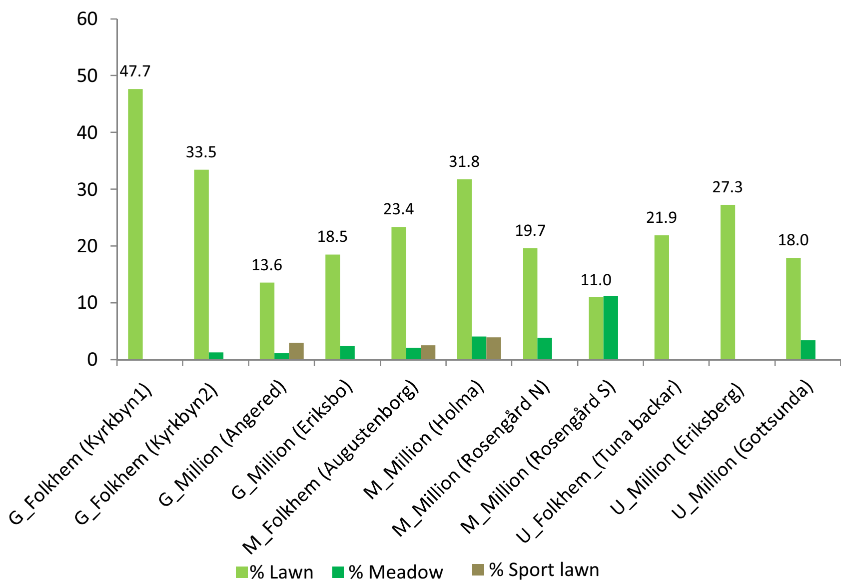

Fig. 5. Total lawn cover by lawn, meadow and sports lawn in each of the study areas (G = Göteborg, M = Malmö, U = Uppsala). Two of the areas were separated into two units (Kyrkbyn I and II in Göteborg and Rosengård N and S in Malmö) to illustrate the potentially large differences in meadow areas and within areas.

activities. One interviewee said: “Since I use a wheelchair I am not outdoors that often. But I enjoy the view from my balcony”.

Lawn enthusiasts argued that lawns are “important places to meet friends”, “important for different kind of activities” and “especially important for families with children”. Urban residents at all sites valued well-maintained lawns in their neighbourhood and were satisfied with municipal management of their grass areas. Only a few respondents were unhappy with noise from a mower or with rubbish left on the lawn (Fig. 6).

In all our research areas, lawns were used for different kinds of outdoor activities during the summer: walking/passing through, playing, sitting, sport, meeting friends, sunbathing and family partying/barbequing. The use of lawns (the particular activity performed most) varied in the different case studies depending on how the lawns were valued.

People greatly appreciated lawns for different kinds of pastimes (Fig. 7). We found that people living in sites with huge open lawns close to the buildings did not use these lawns for any kind of activity, but liked them as a viewing space. This is not surprising, since people see these open green carpets on a daily basis. Many people preferred to have green places in close proximity to their houses, or lawns with a “cosy” or “lush” character.

Observational studies confirmed the questionnaire data on the use of lawns for outdoor activities (Figs. 8 and 9). People mostly passed through or cycled on pathways alongside or through lawns that had no specific attractions such as benches, playgrounds or flowerbeds.

The results showed that people often use the lawns as passages. Some lawns were also often used for walks (especially popular among dog owners). The time citizens spent directly on lawns depended on the quality of the grass and weather conditions. “Popular” lawns all had spots where people were protected from the wind or sun (Fig. 10). Social activities were more frequent in good weather.

The observation studies also showed that residents preferred places where they had a nice view, social activities or something over and above just plain lawn, for example decorative perennials, shrubs or water features.

In the daytime, families with children often used lawns between 10.00 and 15.00. Children were out after school and at the weekends. Dog owners were seen quite frequently from early morning to late evening. Elderly people over 65 used green spaces during the daytime. The weather conditions were important even for dog owners (in bad weather the lawns were used for a very short walk). There were several quite similar patterns in observation studies in all case studies in the Million Programme and People’s Homes sites in all three cities.

Lawns were mostly used in late spring and summer because of the Swedish climate with its defined winter and summer seasons. The questionnaire data supported this finding. Quite a few people

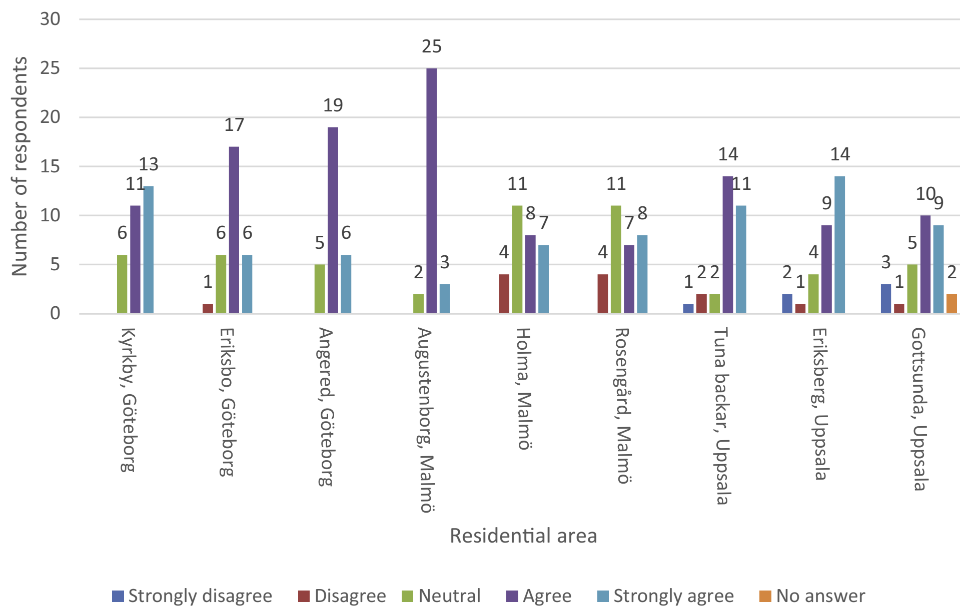

Fig. 6. Importance of well-maintained lawns in multifamily houses (Million Programme and People's Homes).

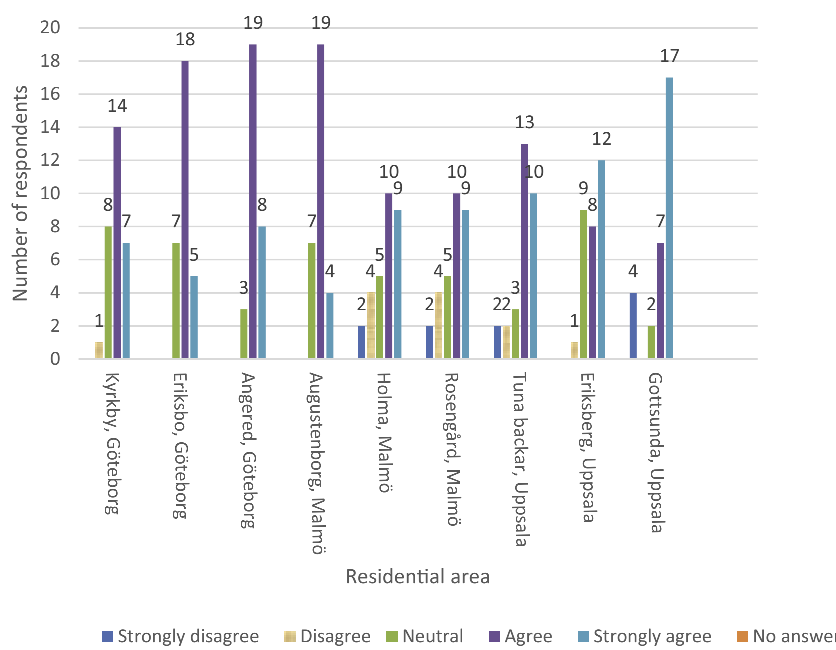

Fig. 7. The value of the lawns as a suitable place for leisure activities.

mentioned the importance of lawns on hot summer days in particular, but some people said that they used the lawn "all year round if the weather is good" and in places where they can enjoy the sun and also get some shade. Some respondents said that they avoided places that are windy, noisy, unattractive, less well managed or containing "unpleasant people".

When asked about lawns as an important aesthetic place, most respondents really appreciated lawn as an "enjoyable" and "beautiful place" (Fig. 11).

Many of the spontaneous comments also confirmed that people like well-maintained green places between and around buildings.

When we asked if lawns generally create a good habitat for small creatures, such as insects, birds and mammals, many participants replied that lawns do not have much value for biodiversity and are not a good place for many living creatures. One of the participants said that the lawn "is not a place for nature, it is cut too often", another said it was "too sterile an environment" and "too monotonous". Others said that the well-managed lawn is nice because you can have a good line of sight. Aesthetic values were often highly appreciated and places with such values were frequently used or visited. The green colour of lawns was also mentioned by people as a valuable feature.

We could see no significant differences in answers between cities as we researched two similar housing types in each city. However we observed some particular attitudes to lawns

in People's Home areas related to particular local geographical or design features. For example, Augustenborg (Malmö) is one of the best examples of the urban eco-concept, with the installation of stormwater management devices such rain gardens, detention ponds, green walls and green roofs. Green areas between

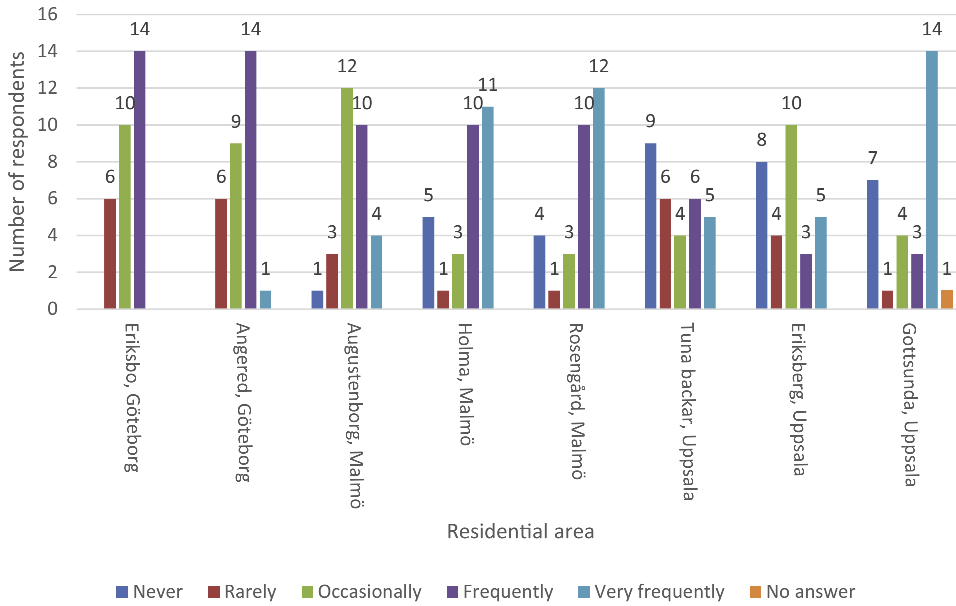

Fig. 8. Usage of lawns as a passage in multifamily housing areas.

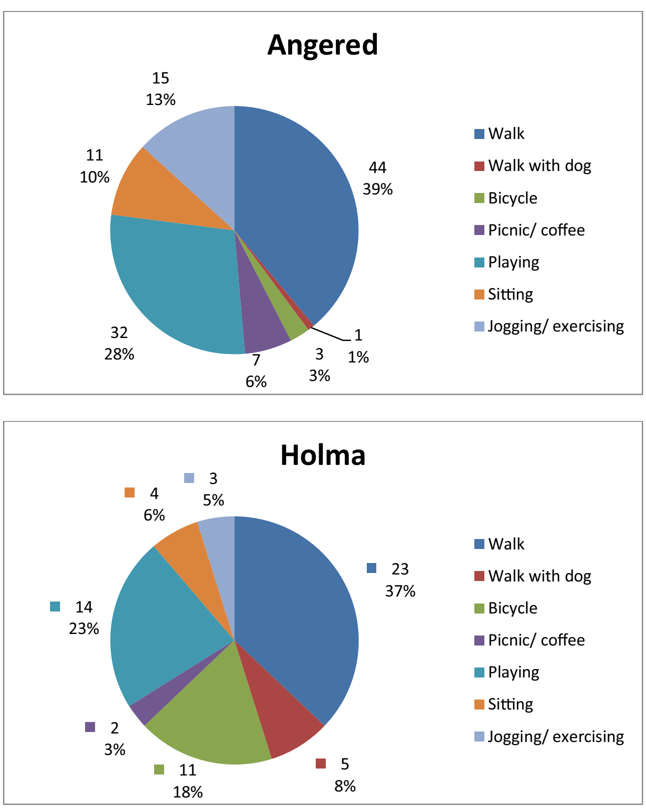

Fig. 9. Two examples of typical activities on a sunny summer day in the two Million Programme areas in Malmö. People often preferred 'mobile' activities on or beside the lawn (pathways).

houses have small ponds. Local dwellers were very proud of their neighbourhood having such an "eco" status and they enjoyed and especially actively used those lawns leading to the ponds. In Kyrkbyn (Göteborg) people were particularly concerned about losing a specific lawn adapted to the local nature, such as a spot (located on an elevated rock) which was about to be removed due to the construction of a new building (densification).

Fig. 10. 'Direct' use of lawn; relaxed reader in Augustenborg (People's Home, Malmö) on a warm day in August 2015.

In Million Programme areas, due to their planning character, there are a lot of unused monotonous lawns (more than in the People's Home areas) and even some "dangerous" lawns which people avoid using because of "suspicious activity".

The most attractive and actively used lawns were those with topographic variation Holma Hills (in Malmö) covered with a conventional short-cut lawn or those turned into a neighbourhood attraction (fountain or playground as in Angered (Göteborg)). In residential areas, lawns with 'attractions' (organised or planned for activities or for the senses) were used much more actively for recreation.

Regarding the answers to question 5 (Fig. 4) about alternative lawns, people had quite a range of opinions. There were some nature enthusiasts who would like to see flower-rich meadows and said that "it is certainly good for the environment" and "it could save money and is worth having", but many people still preferred more tidy, conventional lawns but also argued that meadows could be "very good in some places". Some respondents believed that such places looked untidy and some were even afraid of snakes or ticks in tall grass close to buildings. This opinion can probably be explained by the fact that residents had not previously considered or seen such alternatives.

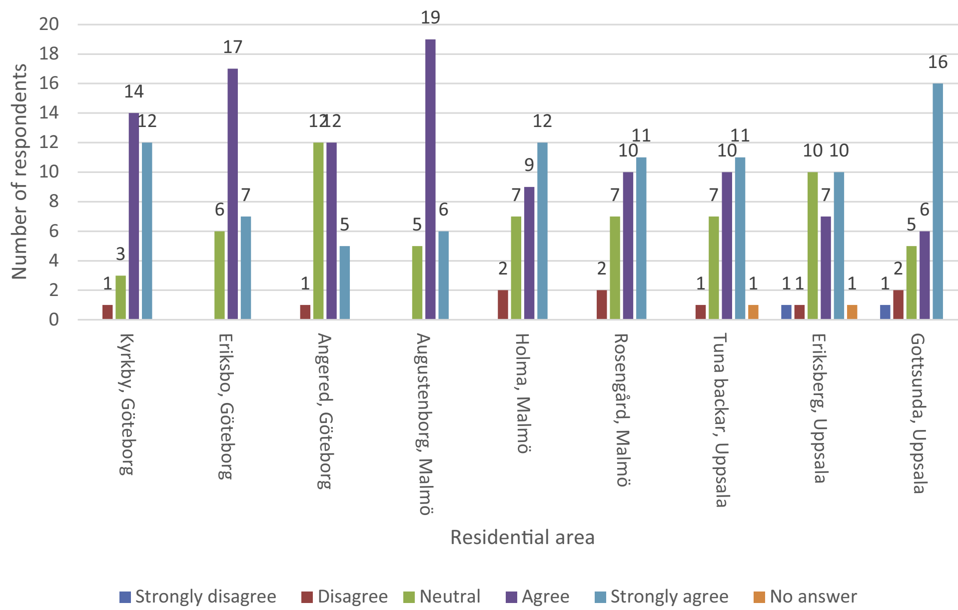

Fig. 11. Aesthetic value of lawns in multifamily housing areas.

Many people found grass-free lawns (lawns with low, flowering native herbaceous species) "amazingly beautiful" (for example 19 of 30 respondents in Kyrkbyn, Göteborg). However, people expressed a fear about walking on such lawns because of possible damage to plants and about picking the flowers, which could destroy the beautiful flowering carpet. One reason for this reaction could be a lack of information or the novelty of this kind of 'lawn'. For many respondents, these kinds of flowery lawns were similar to flowerbeds.

Perennial meadows framed by mown grass areas received positive feedback from respondents in many cases. For example in Kyrkbyn, 22 out of 30 respondents were positive about this design and said that it would be good to have such a meadow since "we have a large area that is not used". They mentioned that "meadows can be good for children; I think more people would be able to appreciate it".

Our third alternative scenario of pictorial annual meadows received less enthusiastic feedback. Respondents thought that this type would be good to use "in large areas not used for other activities" or "outside residential areas". One comment from many people was that they did not want to have such meadows close to buildings.

When we asked what people would like to suggest for improving green areas, they mentioned "have more Swedish flowers", "more colour", "opportunities to have nice seating areas with tables and benches, pieces of art, more trees and water features".

4.3. Managers' and decision-makers' vision of lawns

Managers in all three municipalities had quite similar visions of lawn management. The majority of lawns in Sweden are conventional, regularly-cut grass communities, cut 12–20 times per season to a height of 4–10 cm (Andrén, 2008). However, each municipality surveyed had its own subcategories of conventional lawns and meadow-like lawns, depending on the management regime (number of cuts and removing or leaving clippings on the surface).

Swedish municipalities normally do not use herbicides or pesticides in their management of lawns. Due to the organisational and bureaucratic peculiarities of Swedish municipalities, it was difficult to obtain details about the management and maintenance of lawns. Construction and management were performed in several stages by numerous contractors that often did not follow managers' instructions exactly. A common finding in our interviews with garden managers was their concern about high costs related to lawn management (very frequent mowing of conventional lawns). All three municipalities spent twice as much money per unit area on the management of conventional lawns compared with meadow-like lawns, which was why managers were quite open to considering alternatives to traditional lawns.

Many professional stakeholders interviewed, including landscape architects and park managers, believed that residents want to have short, manicured lawns (Eshraghi, 2014). Managers in Swedish municipalities have a quite practical maintenance "thinking". For example shrubs, trees, rocks and benches were seen as "obstacles" to mowing lawns with water features, such as ponds, requiring great maintenance efforts. The dichotomy is that on the one hand, people in multi-family areas want to have more tables and benches on the lawns, but lawnkeepers often do not like residents eating on these lawns and leaving food leftovers, since this attracts "undesired" wildlife such as rats, rabbits and wasps. On the other hand, some stakeholders stressed that people are interested in places where they live and would like to participate in improving them.

The politicians interviewed were in complete solidarity with the managers and professionals; their definition and understanding of a perfect lawn was a smooth grass surface looking perfectly "green" and "good". "We have to have lawns. They have been here for hundreds of years". However, some of the interviewees in Uppsala stated that plain lawns can be boring and it would be nice to enrich them with other elements such flowers and trees (Eshraghi, 2014). All politicians and professionals (involved in lawn planning, design and management) strongly believed in the recreational, aesthetic, physical values of lawns and its mental health values for citizens. It was also revealing that the majority of politicians and even professionals interviewed were aware of the environmental issues that conventional lawns can cause, but would still prefer "familiar" conventional lawns.

5. Discussion

Our social studies showed that people like lawns even if they do not always directly use them. For the majority of people, lawns are

Fig. 12. "Cues to care" in the Portland neighbourhood in London, UK where meadow is framed by traditional lawn that is actively used by local residents (May 2015).

just a given element of green areas. Lawns cover the most significant amount of outdoor area in most multi-family residential areas and accompany people everywhere. This conclusion corresponded with the main outcome of research by Kaufman and Lohr (2002) on social norms (and the reasons behind it) of well-maintained lawns in front gardens in central Iowa. When the Iowa Turfgrass Industry was asked about the percentage of homes that have a front lawn, the answer given was that it is a universal phenomenon. Despite differences in the planning structure of US and Swedish cities, lawns are a part of the modern urban social psyche. Kaufman and Lohr also argues that from a social point of view, grass "with its aesthetically pleasing colour and uniform texture, fosters a sense of well-being" (Kaufman and Lohr, 2002 p. 293). Another outcome of this US research can be also correlated with our conclusion that having a well-maintained lawn is considered to be the "normative" practice. It is particular supported by the results of our interviews with politicians, urban planners and gardeners in Sweden. The only difference is that private homeowners in the US dominate residential areas and keep their lawns well maintained. The dominancy of the well-kept green carpet can most likely be explained by common knowledge conveyed in the mass media and national and local guidelines on green areas planning, design and management.

Another interesting parallel between the US and Sweden is that not all people adhere to the 'norms' of a manicured lawn. They are called conformists and nonconformists (Kaufman and Lohr, 2002), In our study, when asking question about different options for alternative solutions to lawns, in each case study we had 'nature enthusiasts' who preferred more nature-like 'messy' lawns.

The question of introducing and establishing alternative lawns in the urban environment is being discussed today in Germany, Switzerland, France, Austria and Sweden (Ignatieva and Ahrné, 2013), England (Woudstra and Hitchmough, 2000; Smith and Fellowes, 2014), Australia and New Zealand (Ignatieva, 2010). In the USA, the search for an alternative solution to front garden lawns is especially acute in states such as California, Arizona and Florida with their shortage of water (The Florida yards and neighborhoods handbook, 2015). In Sweden 'pictorial meadows' with annual plants and meadows with native grasses and perennials are established in a few public parks and traffic islands. In our research, alternative lawns were appreciated by many citizens as well as politicians, planners and managers. However, the implementation of new approaches requires special planning and design solutions adjusted for each particular neighbourhood. For example, the residents interviewed here believed that meadows definitely had aesthetic and biodiversity values, but were not useful for some activities and should be located on the periphery of the garden or green area. However, some people were keen to know more about alternative options to conventional lawns. There is a paradox here in people's perception of lawns ("essential", "norm" feature) and the use of lawns in reality. The preference for the middle choice in Fig. 4 (Image 2) out of the three alternatives clearly shows the importance of the 'cues to care' approach when there is a clear indication of the presence of design and human care in meadow-like lawns in residential neighbourhoods (Fig. 12). The 'cues to care' approach was introduced by J. Nassauer as one of the possible solutions for suburban American front gardens (Nassauer, 1995).

There was quite surprising interest and a positive response from Swedish residents to grass-free (tapestry, low-growing flowering perennial herbs) lawns, possibly because modern people are hungry for colour and variety in their cities. Another explanation is a growing awareness and gradual acceptance of 'wild' urban nature (Weber et al., 2014) in some European countries.

Fig. 13. Suggestion for lawn modification in a People's Homes area in Göteborg, with shaded meadows and pictorial annual meadows (Andersson and Bergbrant, 2015).

In other projects related to the recent densification programmes in Swedish municipalities, planners, researchers and residents are concerned with a growing shortage of green space in which to meet, play and enjoy (Berg et al., 2015). The lack of green spaces in dense neighbourhoods also results in less light, more noise and social crowdedness in courtyards and streetscapes. One of the most important conclusions of our research is that people do not want to see a monotonous lawn, but a variety of spaces that provide good conditions for different senses (sound, smell, touch and sight) and social activities. This outcome is directly connected with the initial organisation of the urban planning structure and the creation of varied well-functioning private, semi-private and public outdoor spaces that can be attractive for a whole range of activities (voluntary or self-imposed or social) (Gehl, 2001). Lawns that serve as social meeting and activity points should be intensively managed, while lawns and green spaces that are not used should be considered for alternative designs (Fig. 13). Many urban lawns could have been developed as attractive places and spaces for a variety of activities if planners and landscape designers had originally thought about including elements for the senses and for being active.The planning and design of lawns should be guided by people's need for variety, but also by cost efficiency and environmental benefits.

Acknowledgments

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Estimating urban lawn cover in space and time: Case studies in three Swedish cities

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Abstract Lawns are considered monocultures and lesser contributors to sustainability than diverse nature but are still a dominating green area feature and an important cultural phenomenon in cities. Lawns have esthetical values, provide playground, are potential habitat for species, contribute to carbon sequestration and water infiltration, but also increase pesticides, fertilization, are monocultures and costly to manage at the same time. To evaluate the potential impact of lawns, whether positive or negative, it is of interest to estimate the total lawn cover in cities and its change over time. This is not a straightforward process, e.g., because many lawns are small and covered by trees. In this study we review the existing literature of lawn cover in cities and the different methodologies used for cover estimation. We found both pros and cons with NDVI and LiDAR data as well as manually interpreted aerial photos. The total cover of lawns in three case study cities was estimated to 22.5%. By extrapolating these percentages to all Swedish cities lawn cover was estimated to 2589 km^2 (0.6% of the terrestrial surface). The approximated total municipal management cost of lawns in all Swedish cities was 910,000,000 USD/year. During 50 years lawn area almost doubled in relative cover and 56% of them were continuously managed. Since lawns constitute large parts of the urban greenery and are costly to manage it is highly relevant to consider their social, ecological and cultural value compared to alternatives, e.g., meadows with less intensive management.

Keywords LiDAR · Orthophoto · Grassland · Meadow · Turf · Management

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Introduction

The existing research of urban green areas and their sizes, qualities and areal changes over time have been focusing on urban greenery in general and rarely on urban lawns (also called grasslands, turf grass, meadows) although lawns are common in cities all over the world. Lawns are however mostly noticeable in the western world in particular but through modernization processes in, e.g., China there has been a fairly recent rapid increase in the establishments of lawns (Ignatieva et al. 2015).

The lawn has supposedly become such an important component of cities due to the numerous ecosystem services lawns provide (Johnson 2013); e.g., good opportunities for activity as sport fields promotes good health, visual esthetic values that increase well-being, carbon sequestration, urban heat regulation (Wang et al. 2016) area for water infiltration (Armson et al. 2013), noise reduction (Fang and Ling 2003) and as substrate for biodiversity, especially when managed as meadows (Ignatieva et al. 2015). However, lawns also have negative effects due to the high use of pesticides (e.g., 17% of the insecticides used in USA are used for lawns; Milesi et al.

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2005, but the usage of pesticides vary a lot between different regions of the world), fertilizers, vast water consumption (Runfola et al. 2013) and potentially high management costs. Thus, it is of interest to know the areas of lawns in cities to be able to understand the extent of the potentially positive and negative effects.

The basic problem in estimating size and distribution depend on the fact that lawns are very scattered (small parcels) within the cities. The majority of the existing literature of lawn cover in cities is based on either aerial photos (orthophotos; Akbari et al. 2003; Attwell 2000) or LiDAR data (a surveying method that measures distance to a target by illuminating that target with a laser light, the acronym stands for LIght Detection And Ranging; Han et al. 2014). However, many studies seem to combine different techniques such as aerial photos with other remote sensing data (Robbins 2003; Milesi et al. 2005). Many studies use vague explanations on how lawn areas were defined (Stewart et al. 2009) or equaling lawns with other herbaceous vegetation such as flowerbeds and vegetable patches; (Edmondson et al. 2014). Even detailed studies of urban grasslands such as the one made by Fischer et al. (2013) do not map domestic gardens separately because they are so numerous, scattered and small and thus limits the size to >500 m^2 and, e.g., assume that smaller parks includes grasslands.

Areas of lawns may vary in different urban settings, e.g., residential gardens in the city of Koge in Denmark had 31.4% lawn cover, single family housing areas 31.8%, high density and low rise houses 43.5%, apartments 35.5% and city center 31.3% (calculated from Table 1 in Attwell 2000). Studies do, however, seem to be skewed towards non-public residential areas where residential gardens in Christchurch in New Zealand had 47% cover (Stewart et al. 2009), in the city of Sacramento in USA 24.5% (Akbari et al. 2003), in Sheffield in U.K. 41.5% of the gardens had >75% cover of lawn (Gaston et al. 2005). Robbins (2003) estimated total cover of lawns in private lots on a larger scale (Ohio county in U.S.A) to be 23%. They (Robbins 2003) used black and white aerial pictures of 63 gardens removing tree cover, garden cover (supposedly e.g. flower beds), sidewalks, driveways, porches and considered the remaining area as lawn and extrapolated this onto state size of lots. Milesi et al. (2005) is the only study, to our knowledge, that estimated total cover of lawns in one country (of all types of urban settings). They (Milesi et al. 2005) used an indirect approach removing impervious surfaces, trees and other undeveloped areas and assumed surface of turf grass to be the inverse of that area. Milesi et al. (2005) used a combination of nightlight measures to estimate impervious surface in combination with aerial photos along transects in 13 major urban centers which later were extrapolated to the whole of USA. The results revealed turf grass on 1.9% of the total area of USA (approximately 163,800 km^2).

Milesi et al. (2005) argue that turf grass rarely can be identified using satellite data due to low resolutions. However, since 2005 remote sensing techniques, including high intensity of LiDAR data where multilayers of urban vegetation can be detected, has developed a lot (Han et al. 2014). However, Han et al. (2014) argue that LiDAR data need to be validated in field and that laser data varies in intensity and thus also varies in potential to be used for mapping of urban greenery. In a review of satellite remote sensing in urban settings, Patino and Duque (2013) conclude that many scientists working on regional levels remain skeptical that satellite remote sensing will provide useful information on local scales. Thus, despite the available developed techniques the area of lawns still remains difficult to estimate.

Further, few studies investigated lawn continuity over time although lawns are an old cultural phenomenon, e.g., in Western Europe where they date back to medieval times (Ignatieva et al. 2015). Robinson (2012) has, as one of the few, estimated land cover composition change between 1960 and 2000 at parcel level in an exurban residential area in Michigan USA. The study found an increase in residential areas over time, as well as an increase in tree cover, but that lawns became proportionally smaller when parcels became larger (potentially due to the costs of maintenance of fertilization and the intensity of labor). Huang et al. (2014) used Robinson's results to estimate carbon uptake over time. Fischer et al. (2013) found that historical parks have higher species richness than other grasslands in the city suggesting that there may be a positive relationship between continuity in management of lawns and biodiversity.

The overarching aim of this paper is to use and evaluate different methods to estimate urban lawn cover in space and time in urban areas. We extrapolate lawn cover of three cities to estimate total national cover of lawns in Sweden and a theoretical management cost. We test NDVI (normalized difference vegetation index), LiDAR and aerial photos and discuss the potentials of each method for estimating urban lawn cover. We estimate how large proportion of present lawns that have been managed for more than 50 years using black and white aerial photos from the 1960's. Finally we discuss how of present lawn area and the changes over time affect the potentials for different ecosystem services.

Methodology

Study sites

Three major cities in Sweden are used as case study cities, Gothenburg (550,000 inhabitants and sized 45,000 ha), Malmö (270,000 inhabitants and sized 7681 ha) and Uppsala (140,000 inhabitants and sized 4877 ha). The cities are located in the Southern third of Sweden (South of the river Dalälven), where more than 86% of the Swedish population lives (Statistics Sweden 2012). These cities are among the four largest cities in Sweden (only Stockholm is larger) and are located in different parts of Sweden and in different landscape context. Malmö is situated in an agriculture dominated area in the south, Gothenburg in a forested area with a lot of bare rocks on the west coast and Uppsala is based in a landscape consisting of mixture of forest and agricultural land (approximately 50% each) in eastern Sweden. They represent potentially different climate conditions and local cultures in management and establishment of lawns (Ignatieva et al. 2015). These three cities are further studied in a major transdisciplinary project about lawns where two urban Multi-family residential housing neighborhoods that are rather unique for Sweden are investigated; Million program Housing and Post war "Peoples home" where approximately 50% of the Swedish population live (see Ignatieva et al. 2015). In Sweden 85% of the population live in urban areas (Statistics Sweden 2012).

Public lawns in Swedish cities are managed both by municipalities and private owners. It is common that, e.g., people in multifamily housing own the lawns and manage them but still allow the public to use them. In, e.g., Uppsala the Swedish church and two Universities are major land owners beside the municipality, and manage their own lawns of which all are open for public use. Ownership of urban green areas in Gothenburg (G), Malmö (M) and Uppsala (U) is; Private person (G = 20%; M = 22%; U = 18.1%); Official institutes such as municipalities, universities etc. (G = 56%; M = 54%; U = 56%); Stock companies (G = 10%; M = 9%; U = 9%); Private or municipal tenants (G = 7%; M = 10%; U = 10%); Other or Unknown ownership (G = 7%; M = 4%; U = 8%) (from Statistics Sweden 2015). Thus it is difficult to know the area of lawns of an entire city through municipality protocols of lawn area management only. The municipality of Gothenburg manages a lawn area of 427.5 ha, in Malmö 516.3 ha and Uppsala 681.4 ha (information from nature and planning departments in Gothenburg, Malmö and Uppsala). The lawn areas that are municipality managed do not use fertilization or pesticides for maintenance (information from nature and planning departments in Gothenburg, Malmö and Uppsala municipality).

Mapping methods - LiDAR and NVDI

Light detection and ranging (LiDAR) data is based on illuminating a target with a laser beam, usually within the near infrared (NIR) wave lengths (reflecting a target on the ground that reflects up to e.g. an airplane with device). Each LiDAR return contains an intensity value (0 to 255) which depends on the reflectivity of the surface. Vegetation provides a relatively high intensity value due to its high reflectivity in the NIR wave lengths. The Normalized difference vegetation index (NDVI) is a value that can be calculated from the amount of light reflected in an image band of wavelengths in the near-infrared and red light. The index usually use images from space satellites, and indicates the amount of living vegetation. Normalized difference vegetation index is used for vegetation analyzes. This works because the vegetation often has high reflection in the NIR band and low reflection in the red visible band.

Gothenburg had high intense LiDAR data available and was thus used to test a method for estimating lawn cover. A smaller area (2 km^2) of the south central Gothenburg was chosen as a study area for LiDAR and NDVI studies (this area had suburban character, a mixture of multifamily housing and small private houses in Sweden; see Vogel 2014 for details). Orthophoto and LiDAR datasets was provided by the Building and Planning authority of the city of Gothenburg (Stadsbyggnadskontoret). The LiDAR data was collected at a height of 550 m with a swath angel of 20°. It covered all of the study area and had 13.65 returns per m^2, each point with a 0.13 m diameter footprint (the area of the pulse when it hits the ground). The LiDAR data was classified into 10 classes, where class 1 (unassigned) and class 2 (ground) were of specific interest to this project and was gridded at a resolution of 1 m. Especially class 1 showed after a closer inspection to reflect pulses near ground level or on ground level, indicating potentials for high level of return pulses for lawns.

The orthophotos had a resolution of 0.25 m. The photos contained both IR and visible bands. A vector polygon dataset of all grass areas maintained by the municipality was used as a complement to the analyses. However, the municipality in Gothenburg (and Sweden in general) only manages their own lawns which are a fraction of total urban lawns.

To be able to extract the lawns from the intensity raster (LiDAR), an intensity threshold value was required. Based on manual comparison of the intensity raster and lawns visible on the orthophotos, and distribution of the intensity values of pixels in the municipal maintenance grass areas, the threshold was set to 150 (see Vogel 2014 for details). Since not only grass show intensity values >150, but also areas such as white paint on roads and other highly reflective surfaces, it was necessary to find a way to minimize the number of pixels indicating false grass surfaces. To do this, the raster was first run through a Majority filter tool; if a pixel has another value than at least 3 of its 4 cardinal points, the pixel gets the value of these 3 neighbors. In this process, outliers such as single non-grass pixels inside a grass area or grass pixels in the middle of a road, was removed. A region group tool was used, which groups any connecting clusters of pixels of the same value and gives the group a unique ID. To further filter out non-grass areas registered as grass, a grass area threshold value was set at 7 m^2 and all groups with an area smaller than this was removed. The threshold was set to 7 m^2 after visually comparing the results of different thresholds between 10 m^2 and 5 m^2 in the study area with the intention of keeping the threshold as low as possible while still removing the majority of non-grass surfaces registered as grass.

Mapping methods – aerial photos

In this study we used ArcMap 10.2 and the aerial photos included in the ArcMap background data from May 2015. The map features 0.3 m resolution imagery in parts of Western Europe (DigitalGlobe). The lawns were manually mapped (polygons) in three gradients from the urban fringe to the center part of the three cities Gothenburg (length of gradient =10,200 m), Malmö (length of gradient =7000 m) and Uppsala (length of gradient =5100 m; see Fig. 1). Gradients were located to cover largest possible length of urban areas, not crossing major rivers or lakes and leap in different directions (south–north in Gothenburg, east–west in Malmö and north-south in Uppsala). Four ha squares were interpreted every 500 m making the total interpreted area in all three cities 132 ha ($N = 33$ squares × 200 × 200 m). In Gothenburg $n = 15$ squares, Malmö $n = 10$ squares and Uppsala $n = 8$ squares.

All three cities have an outer border (urban fringe) defined by the statistics Sweden (Statistics Sweden 2013) and were clearly visible in the photos. The center (end) of transects were the medieval inner cities (e.g., in Uppsala the center is in the Castle originally built in 1549 A.D.). Prior to aerial photo interpretation a pretest using drones with high resolution photos was made showing that ArcMap background data had lower resolution but still enough for the purpose of interpreting lawns (i.e., drones would not add additional important information of lawns at the scale of cities but perhaps for local, in detail, studies of single urban green areas).

In each 4 ha square the total area of lawn, meadow (grass that according to municipalities in Sweden are only cut once or twice a year, information from nature and planning departments in Gothenburg, Malmö and Uppsala municipality), sport lawn (soccer fields), trees, shrubs, gravel (sport fields with gravel), bare rock (mountain rocks, very common in Gothenburg), bare soil, water, agricultural fields, bare soil and allotments (small scale gardening) were mapped. Land cover not classified as any of these categories was considered infrastructure (e.g., roads, houses, parking lots, industrial areas etc.). Subsamples of some areas in Uppsala were visited in the field to confirm cover under trees. In areas available for everyone, such as around churches and parks the areas underneath the trees were often (not always) covered by lawns. When some areas were hidden by shadows or trees Google earth street view was used to get an overview of the area. This was mainly done for areas shadowed by houses and trees in all areas except for gardens since it was difficult to see due to hedges and shrubs.

To investigate land-use and lawn cover in historical maps the same 4 ha squares were manually interpreted using black and white aerial pictures from Lantmäteriet (Swedish authority for property registration and geographical information). The photos varied in age between 1956 and 1963 depending on city and location along the gradients, but will hereafter be referred to as the 1960's photos (although in some cases dating further back). The orthogonal projections of aerial (ortho) have a resolution of 0.5 m (local variations may apply depending on flight height). Photo shooting took place mainly from 4600 m above sea level with scale at around 1:30,000 where scanning was made with 15 μm providing a resolution of 0.5 m / pixel.

Present cover that overlapped with cover in the 1960's was considered to be continuity lawns.

Fig. 1 Illustrates the methodology of how interpreted squares were chosen in the cities, Here illustrated by Uppsala city. The gradient of $N = 8$ squares (200 m^2, 4 ha) reaching from the urban fringe (upper corner) to the center of Uppsala (lower part of photo)

Results

LiDAR and NDVI

Using LiDAR a significant number of pixels indicated grass although located at roads where there is no grass in reality (for details see Vogel 2014). After filtering and limiting smallest grassland to 7 m^2 a lot of "road" grass disappeared. In the investigated area of 430.3 ha 56.9 ha were detected as grass, i.e. 13.6%. The IR (NDVI) captured vegetation very well but had major faults in distinguishing grass from shadows (see Fig. 2).

By comparing the municipally managed areas (with rather precise cover of lawn) with LiDAR data the results showed that the LiDAR detect about 42.6% of the total municipal lawn areas, the rest of the existing municipal lawns were classified as forests. Thus, LiDAR detected 13.1% although in this subsampled areas of Gothenburg it should be closer to 31% (Vogel 2014).

Lawn cover in three cities

Using manual interpretation revealed similar problems as the LiDAR data revealing that it was difficult to estimate lawn cover under deciduous trees. However, in contrast to LiDAR many of the aerial photos of the cities were taken prior to

Fig. 2 Detailed comparison of filtered LiDAR-based grass raster and NDVI raster. (**a**) show the basic orthophoto. (**b**) show the orthophoto overlaid by the filtered LiDAR based raster. (**c**) show the NDVI raster. The red circles indicate areas of interest. It is apparent from looking at all 3 circles that NDVI, in contrast to LiDAR, does not capture vegetation in shaded areas. When comparing (A) and (C) it can also be noted that it is hard to distinguish trees from grass in (C), (**d**) shows the intensity of LiDAR (modified from Vogel 2014)

leafing (May) which meant that it was possible to see the potential lawn cover under deciduous trees. Further, field visits and Google earth street map view helped in interpreting the maps in some situations. However, when there was coniferous trees (not revealing the substrates underneath) the area was interpreted as tree cover and not lawn.

The total cover of lawn in percent, based on a mean of all three cities was in 2015; 22.5%. In Gothenburg 15.0% (equivalent to 6750 ha lawn), in Malmö 20.5% (equivalent to 1578 ha lawn) and Uppsala 31.9% (equivalent to 1557 ha lawn). If merging all city area and lawn areas together (giving Gothenburg substantial relative more weight in the test since it has 15 transects) the total lawn area would be 20.8%. The lawn cover varied a lot between cities and along the gradients depending on the dominating type of housing areas (Fig. 3). Since the gradients were randomly positioned it was difficult to estimate the specific type of urban setting (e.g. residential areas, churchyards, parks etc.) affecting lawn cover along the gradient (in many places residential areas and multifamily housing were located together) although a general pattern was that lawn cover decreased along the gradient (Figs. 3 and 4). The lawns consisted of three different types, lawn (16.5%), meadow (3.3%) and sport lawn/soccer field (1%) in all cities combined.

The total cover of lawn in percent in 1960, based on a mean of all three cities was 12.6%. (Gothenburg 13.8%, Malmö 6.1% and Uppsala 17.8%). Here, the much lower cover of lawn partly depends on higher proportion of agricultural areas and allotments in the 1960's. (see Fig. 5 and Continuity of lawns below). Due to the low resolution of the black and white photos, taken 1960, it was difficult to distinguish meadows from lawns.

Based on our lawn estimations of each city, lawn consisted of 51.8% of the total green cover in these three cities (based on green cover estimation in Statistics Sweden 2015 which does not define lawns in specific). Thus, of all green areas in Gothenburg 52.5% was lawn, in Malmö 44.3% and Uppsala 58.9%.

Total lawn in Sweden

Since the LiDAR data missed approximately 57.4% of the "true" cover of lawns when comparing with the precise data from the municipality management plans, manual aerial picture interpretation was used to estimate cover of lawns in cities instead. Total urban land in Sweden is 1,150,450 ha (Statistics Sweden 2013) and assuming that the 22.5% cover of lawn is representative for all cities in Sweden results in a total area of lawn of 258,851 ha (2589 km^2). This represents 0.64% of the

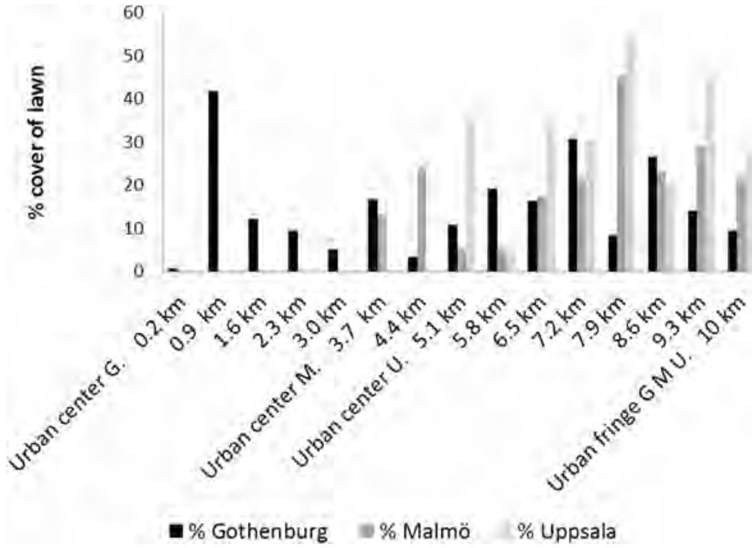

Fig. 3 Cover of lawn in each of the three cities along a gradient from urban center to the urban fringe in 2015. G = Gothenburg (total distance of gradient is 10 km) have 15 squares M = Malmö (6.5 km) have 10 squares and U = Uppsala (5.1 km) have 8 squares

Swedish terrestrial surface (2589 km^2/407340 km^2; Statistics Sweden 2013). However, large parts of the mapped areas were covered by coniferous forest, thus it was difficult to detect if lawns were underneath (even when using Google earth street view). If assuming the proportion of grass underneath is similar to the undetected lawns found under trees in Gothenburg when municipal management maps were used in Vogel (2014) would add 8.3% lawns in Sweden. Thus, that would increase the lawn estimation in cities to 30.8% (22.5% + 8.3% = 30.8%) with an area of 354,339 ha (3543 km^2, 0.9% of terrestrial surface). If all tree cover equaled lawn cover, the total terrestrial cover would be 407,259 ha (4072 km^2; 1% of terrestrial surface) but the true value is probably somewhere halfway (see discussions). No records of lawns underneath shrubs have been reported from any of the cities, thus we treat shrubs as totally lawn free areas.

Continuity of lawns

12.6% of the urban land is lawns with a continuum of at least 65 years. Thus 56% of the lawns in 2015 were equal to the ones in 1960 (12.6% / 22.5% = 56%). However, the outer 5 of the 15 squares in Gothenburg were agricultural areas or forest in 1960 and thus without lawns (Fig. 6). The patterns of continuity of lawn are difficult to compare along the gradients since the gradients were of different lengths in each city.

If all urban fringes in the 1960's are merged together (Fig. 6) the patters of continuity over the gradient resembles with highest continuity of lawns in the outer borders of the cities and lower towards center Uppsala center is an exception where the final square is in a botanical garden making the continuity of grass very high.

Management and costs

The total lawn cover estimated in this study was 9885 ha based on 22.5% coverage. Thus, on average 16.3% of the lawns in these cities are managed by the municipalities (in Gothenburg 6.3%, Malmö 32.7%, Uppsala 43.8%), the rest are privately managed.

Fig. 4 Illustrating three areas in the outer fringe of southern Gothenburg in 2015 on the left (upper square industrial area, middle multifamily housing and lower shows private houses) and the very same area in the 1960's where no houses or industry areas exists (only forests or agricultural areas)

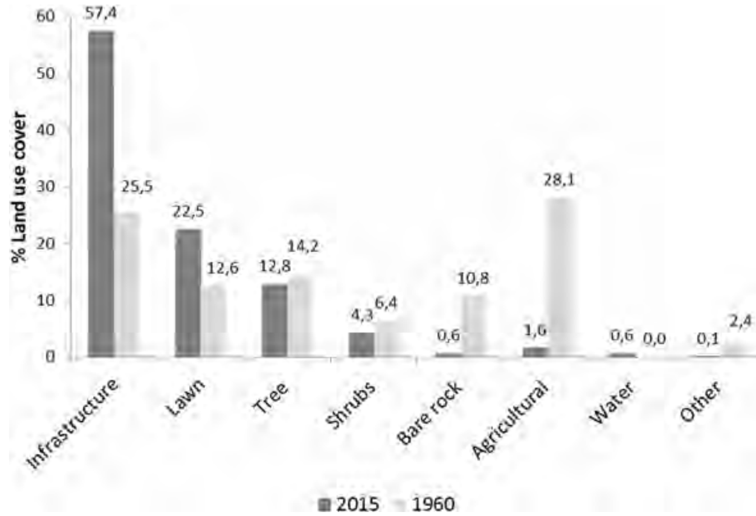

Fig. 5 Average land use cover of each of the three city areas in Gothenburg, Malmö and Uppsala in 2015 and in 1960. "Lawn" consists of all grassland types found in cities such as lawns, meadows and soccer fields. "Bare rock" is mainly occurring in Gothenburg. "Other" consist of areas that seemed to be gravel or bare soil

The costs of managing lawns in Gothenburg is 27,368 SEK/ha (3234 USD/ha), in Malmö it is on average 39,261 SEK/ha (4640 USD/ha) and in Uppsala 9601 SEK/ha (1134 USD/ha) (information from the Park and Nature department of each municipality). The average costs of all three cities is then 32,336 SEK/ha (3822 USD/ha). Thus, the management costs of lawns in all Swedish cities would be 8.37×10^9 SEK (32,336 SEK/ha × 258,851 ha) which is approximately 9.10×10^8 USD/year. The management costs only include cutting and maintaining lawns (dressing by occasionally adding soil and by cutting leaves in autumns) and not additional fertilization, no watering or pesticides since municipalities in Sweden do not use them.

Discussion

Total lawn cover in cities

The estimate of lawn cover with our method was on average 22.5% of the total city area and if extrapolated, 0.6% of the total terrestrial surface of Sweden (compared to USA where lawn was estimated to cover 1.9% of the area; Milesi et al. 2005). Although mapping was made in aerial photos prior to leaf setting on deciduous trees it was still not possible to detect lawn under coniferous trees (unless seen by Google earth street view or field visits). Some areas were found to be forests with bare-rock and no undercover vegetation (especially in Gothenburg), thus making lawn cover and total tree cover ratios equally was

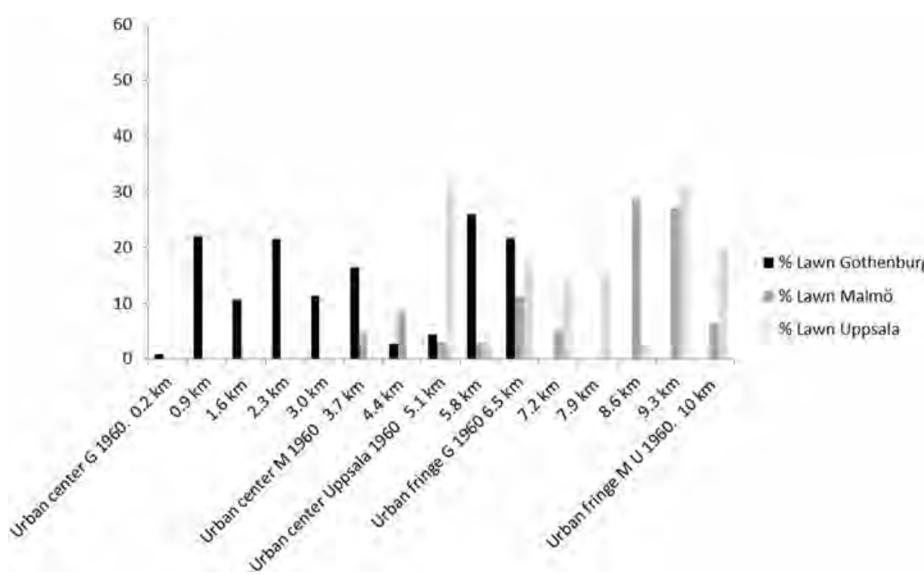

Fig. 6 The lawns cover along an urban gradient from the urban fringes to urban centers in 1960 in three cities. The urban fringe and centers in Malmö and Uppsala were the same in 1960–2015 (the gradient distances were the same, 8 respectively 10 squares). The urban fringe in Gothenburg was 3.5 km further out in 2015 (10 squares in 1960 and 15 squares in 2015)

not an option. However, most probably some of the mapped trees had lawn underneath and thus the lawn cover would most accurately be described as between 22.5% and 30.8% (0.6–0.9% of total terrestrial land use in Sweden).

The national cover is rather speculative since we only use subsamples of three cities (0.2% of total urban area in Gothenburg, 0.5% in Malmö and 0.7% in Uppsala) and the variation of lawns is supposedly substantial between different locations in each city and also different locations in Sweden depending on urban development and size of cities. However, total areas of the case study cities are 6.1% of the total urban cover in Sweden (based on Statistics Sweden 2012) and these cities are further presumably rather representative for urban green cover in the cities in southern Sweden (>86% of the population live) due to that their locations in three different dominating landscape types.

Comparisons between cities within Sweden and in other countries are difficult because many studies only focus on single cities or parts of the cities. If we assume that the 1.9% lawn cover in Milesi et al. (2005) was representative for cities in USA the lawn cover would be 42% (based on an urban cover of 4.5% in USA). Thus, it might be possible that the urban lawn cover in USA is twice in cities although the explanation could be due to that cities or urban areas were not clearly defined in Milesi et al. (2005) and presumably conditions that not exists in Sweden (such as low urban density and large parcels in urban sprawl areas) were included in their study.

Different methodologies and tree cover

In this study we used both LiDAR data and manually interpreted aerial photos. Each method has its pros and cons. LiDAR can easily detect numerous small and scattered lawn areas over large areas with low effort in time which contrasts the labor intensive digitizing of lawns manually (Robinson 2012) from aerial pictures. However, the methodology of LiDAR setting e.g., linking lawn to different intensity could initially be time consuming. The intensity of the LiDAR further varied quite much in the larger scale (of the entire city of Gothenburg) which depended on inaccurate calibration between the collection events (Vogel 2014). This meant that it was not possible to use the same grass thresholds (a value of >150 where grass was detected) for the whole of Gothenburg and further the data was separated into tiles making it impossible to manually set different intensity thresholds. This could however be avoided if the operators of LiDAR made intensity more even. A major obstacle with LiDAR was the difficulties in detecting lawns underneath trees with detection rate as low as approximately 43%. However, we see large potentials in further developing a grass area identification LiDAR model including estimations of grass covered by trees.

The manual photo interpretation method makes it possible to detect variations in the landscape and rather exact map lawn borders. In our case we could also use photos that revealed grass under trees to a large extent. However, it is time consuming to manually make polygons of each small lawn (approximately 4500 polygons in this study), and in addition LiDAR data is objective as opposed to aerial interpretation which is a subjective evaluation of borders and features. As for the black and white photos from the 1950s and 1960s the resolution made it difficult in some cases (not all) to detect differences between shrubs versus trees and lawns versus potential garden plots (in figures merged to "allotments").

Thus, using LiDAR in our study underestimated lawn cover due to shade effects and tree cover. Tree cover is handled very differently in studies of lawns. Huang et al. (2013) used LiDAR and IR (infrared) orthophotos in a 300 ha area in Shanghai (China) to develop an automated method for calculating total urban green volume where all green areas not classified as trees were considered to be grasslands. Milesi et al. (2005) had an opposite approach assuming that tree cover was equivalent to lawn cover. However, in the case of Milesi et al. (2005), this might provide an overestimation of lawns since, e.g., studies in USA showed that in non-residential areas 50–70% of the areas under the canopies were paved surfaces and 35% in residential areas (Akbari et al. 2003). This bias of potential overestimation due to tree cover is especially pronounced if cities with large areas covered by such trees as in Northeastern USA where on average one third of urban land is covered by trees (Dwyer et al. 2000). This illustrates the problem with estimating true lawn cover in relation to trees.

Due to the labor intensive mapping we used a subsample of 4 ha areas along gradients and not total cover. Gradient analyses are to some extent questioned since cities of today does not clearly have a center and a border but are conglomerates where smaller cities are merged into each other (McDonnell and Hahs 2008). However, Swedish cities in general and these three cities in particular, do have clear urban fringes and defined medieval city cores.

The semi-objective sampling using 4 ha every half km is supposedly better than subjectively defining housing typologies since the borders of the housing area sets the limits for lawn estimations. For example, in a study investigating three typologies of housing in Sweden (residential gardens and two types of multifamily housing areas) the average cover of lawns were 27.8% (5.3% higher than in this study; Ignatieva et al. 2017).

Land use of lawns along gradients

Lawn cover varied between cities (15–32%) and along the gradients (5–55%) in 2015 (Fig. 3). General patterns along the gradients were that cover declined towards the city centers (in Gothenburg not as evident as in the other cities). This is most probably because cities in Sweden are denser towards the center. However, some clear exceptions are seen in Fig. 3 where high peaks in the center of Uppsala are due to a botanical garden and a high peak close to the center of Gothenburg is a major urban park. The general pattern of housing types along gradients was; residential areas and industrial areas in the fringes followed by multi-family housing (often highest coverage of lawns) and closer to centers with dense multifamily housing.

The lower cover of lawns in Gothenburg (7.5% lower than average) could be explained by large parts of bare rock (due to Gothenburg's location close to sea) and that it as a major city (with approximate 500,000 inhabitants) includes many industrial and densely populated areas along the gradient. An explanation to the high cover of lawns in Uppsala (9.4% higher than average) could be that the gradient did not cover any industrial areas or that it included multifamily housing areas such as the million program housing known for high lawn coverage.

Lawn cover along the gradient in the 1960's was much lower than in 2015 (Fig. 5). This is most probably due to a higher proportion of agricultural areas along the gradients. Further, it seemed as numerous residential areas had more garden plots (allotments in figures) or bare soil (bare soil was typology "other" in Fig. 5). Surprisingly, in Gothenburg, some places having bare rocks in 1960 had residential areas with lawns in 2015.

Continuity of lawns

56% of the lawns (or meadows) in Swedish cities in the 1960's remained lawns 50–60 years later (12.6% of the average cover of lawns in cities 2015 were the same as the ones in 1960). The highest cover of lawns with long continuity was found in all three urban fringes in the 1960's which resembles the patterns of lawns in 2015. As visual sized by the photos from 1960 many residential areas had allotments/garden plots instead of lawns and many gardens has since the 1960's densified and added one or more houses in the same garden reducing original lawns.

Since all three cities are old (at least a 500 years e.g. Uppsala have houses dating from 1280 A.D.) some of the present lawns may have been pastures or meadows for much longer than 50 years. The continuity of lawns as grasslands is important to biodiversity since they may have older seedbanks (Gustavsson et al. 2007), e.g., historic urban parks in Berlin have high species richness due to their habitat continuity (Fischer et al. 2013; Maurer et al. 2000). Thompson et al. (2004) found that lawns in cities had relatively well-defined plant communities with a species pool comparable in size to that of semi-natural grasslands. Although not suggested in Thompson et al. (2004) their unexplained higher diversity in lawns further from the city border of Sheffield may have been an effect of long continuity.

Ecosystem services and management

In Europe (and Sweden as well) there is an outspoken densification trend leading to reduction in available green areas per person (Statistics Sweden 2005) at the same time as new research highlight their importance for ecosystem services (Haase et al. 2014). Lawns in Swedish cities dominated the urban green with more than half of the areas being lawns and thus being potentially important as ecosystem service supporters.

However, management of lawns is costly. Reducing the cutting frequency to once or twice a year could make the lawns more meadow like and potentially provide a higher species richness of plants and butterflies and increase public enjoyment (Garbuzov et al. 2015). Already today 3.3% of the lawns were less often mowed (meadow typology). With longer continuity and low frequencies of mowing, in combination with removal of the grass-cuttings, existing grasslands could get more similar to semi-natural grasslands. It is obvious that urban lawns and meadows have an important role to play in the future landscape when it comes to grassland biodiversity. It is important to educate decision makers and practitioners of the connection between management for biodiversity and for beneficial ecosystem services. The management costs for lawns in this study varied highly between cities where e.g. Malmö had almost 4 times higher costs than Uppsala per hectare, this large variation should be further investigated.

The trend of increased densification of cities reduce availability of urban green per person in Gothenburg from 281 to 272 m^2 per persons during 5 years (exemplified year 2000–2005), in Malmö 154–153 m^2 and in Uppsala 261–251 m^2; Statistics Sweden 2005). Urban green is used for recreation and important to human well-being. However, lawns are not considered being as high contributors to well-being as forests (Tyrväinen et al. 2014) and more nature like areas (Ode-Sang et al. 2016). Studies even show not even private house lawns are seldom used (Norlin and Wissman unpublished).

Since lawns constitute such large part of the green areas in cities they are also an important part of the urban green areas citizens encounter in their everyday life. Thus, it is crucial for an ever increasing urban population to fully consider the social and ecological value and constraints of lawns. Finally, in order for decision makers to value lawns for their ecosystem services in relation to other urban green areas and the increasing need of green infrastructure reliable methods to measure lawn area and changes in time are important.

Conclusions

The methodologies tested in this study both had pros and cons. LiDAR data was very low in labor intensity (once the semi-automated procedure was established) while manually interpreted aerial photos took long time handling. Aerial photos enabled good detailed accuracy as for estimating borders and sizes of lawns while LiDAR made automatic estimations that sometimes included shadows and roads. The manually made polygons of lawn also have drawbacks since they are based on the interpreter's subjective interpretation in aerial photos while the estimates using LiDAR are objective. Major obstacles were how to do estimates of lawn cover beneath trees. LiDAR severely underestimated lawn cover under trees and aerial photos made it possible to find photos taken prior to leaf in spring. However, we predict that the future lies within LiDAR where new models will be able to identify estimations of grass overgrown by trees.

The estimated lawn cover was estimated to be between 22.5% and 30.8% (0.6–0.9% of total terrestrial land use in Sweden) depending on forest cover. Approximately 56% of the lawns were managed during the last 50 years. The yearly cost of managing lawns in the whole of Sweden (based on approximation of lawn covers of three cities and their average lawn cost per ha) was 9.14×10^8 (USD per year). Half of the urban green areas in cities constituted of lawns. Thus, it is important to consider social, ecological and cultural values of lawns compared to alternative urban greenery or alternative management of lawns as e.g., meadows with less intensive cutting regimes.

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Effect of grassland cutting frequency on soil carbon storage – a case study on public lawns in three Swedish cities

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Abstract. Soils contain the largest terrestrial carbon pool and thus play a crucial role in the global carbon cycle. Grassland soils have particularly high soil organic carbon (SOC) stocks. In Europe (EU 25), grasslands cover 22 % of the land area. It is therefore important to understand the effects of grassland management and management intensity on SOC storage. City lawns constitute a unique study system in this context, since they provide a high functional diversity and thus a wide range of different management intensities per unit area. In this study we investigated frequently mown (on average eight times per season) utility lawns and rarely mown (once per season) meadow-like lawns at three multi-family housing areas in each of three Swedish cities: Uppsala, Malmö, and Gothenburg. The two different lawn types were compared regarding their aboveground net primary production (NPP) and SOC storage. In addition, root biomass was determined in Uppsala. We found significantly higher aboveground NPP and SOC concentrations and significantly lower soil C : N ratio for the utility lawns compared with the meadow-like lawns. On average, aboveground NPP was 24 % or 0.7 Mg C ha^{-1} yr^{-1} higher and SOC was 12 % or 7.8 Mg ha^{-1} higher. Differences in SOC were well explained by differences in aboveground NPP ($R^2 = 0.39$), which indicates that the increase in productivity due to more optimum CO_2-assimilating leaf area, leading to higher carbon input to the soil, was the major driver for soil carbon sequestration. Differences in soil C : N ratio indicated a more closed N cycle in utility lawns, which might have additionally affected SOC dynamics. We did not find any difference in root biomass between the two management regimes, and concluded that cutting frequency most likely only exerts an effect on SOC when cuttings are left on the surface.

1 Introduction

Soils contain the largest terrestrial carbon pool (Chapin et al., 2009). The balance of soil organic carbon (SOC) inputs and outputs is therefore critical for the global carbon balance and thus for the concentration of greenhouse gases in the atmosphere. Globally, 3650 Mha or 68 % of the total agricultural area is used as pasture or meadows (Leifeld et al., 2015). In Europe (EU 25), grassland covers 22 % of the land area (Soussana et al., 2007). Grassland soils store among the highest amounts of SOC, which is primarily related to the high belowground carbon input by roots and their exudates (Bolinder et al., 2012). Soils rich in SOC are potential hotspots for CO_2 emissions when a management or land-use-change-induced imbalance in carbon input and output occurs. It is therefore important to understand the effect of management practices on grassland SOC storage. It has been demonstrated that the type, frequency, and intensity of net primary production (NPP) appropriation (harvest) can play a crucial role for the carbon balance and SOC stocks of grassland ecosystems (Soussana et al., 2007).

One direct management intensity effect on SOC which is mediated by grazing, cutting, or fertilisation regime is obviously the change in carbon input via the degree of biomass extraction and altered photosynthetic activity (Wohlfahrt et al., 2008). Furthermore, above- and belowground allocation patterns may change with cutting frequency (Seiger and Merchant, 1997). Recently, Leifeld et al. (2015) reported faster root turnover in moderately and intensively managed alpine grasslands than at less intensively grazed sites. They concluded that management is a key driver for SOC dynamics and should be included in future predictions of SOC stocks. Nutrient status, species composition, and diversity are highly management-dependent and interfere with the carbon cycle in several ways, including effects on the decomposer community and its substrate use efficiency (Ammann et al., 2007; Kowalchuk et al., 2002).

Management effects on SOC are presumably smaller than land use change effects such as conversion from permanent pasture to arable land (Poeplau and Don, 2013) and might not be visible in the short term. To assess those changes, it is therefore important to find suitable study systems with long-lasting strong contrasts in management intensity over a limited spatial scale and with limited soil variability. For agroecosystems, this situation is usually created in long-term experiments which are designed to study such questions. In a global compilation of all existing agricultural long-term field experiments, only 49 out of > 600 experiments are listed as including permanent grassland (pasture or meadow) (Debreczeni and Körschens, 2003). Thus, the current quantitative and mechanistic understanding of grassland management effects on SOC stocks is certainly limited, since existing studies are often strongly confounded by external factors such as elevation gradients (Leifeld et al., 2015; Zeeman et al., 2010). As an alternative to long-term plot experiments, urban areas can be appropriate study systems. Lawns, public green areas, and parks are omnipresent in urban areas and are usually managed in a similar way for a long time, so that, depending on the prior land-use-type equilibrium, SOC stocks might be approximated (Raciti et al., 2011). Over a comparatively small spatial scale, a wide range of different management intensities can be present.

Urban areas are more rapidly expanding than any other land-use type (Edmondson et al., 2014). Turfgrass lawns cover the majority of all green open spaces in urban landscapes (70–75 %) according to Ignatieva et al. (2015). It has been estimated that turfgrass lawns cover approximately 16 Mha of the total US land area, which in the 1990s was 3-fold the area of irrigated maize (Milesi et al., 2005; Qian et al., 2010). Although robust global estimates of the coverage of turfgrass lawns are scarce, these few existing figures indicate the potential importance of lawn management for the global carbon cycle. Furthermore, several studies have reported higher SOC stocks under urban land use as compared to surrounding soils, which might be a feature of high management intensity in urban ecosystems (Edmondson et al., 2012; Pouyat et al., 2009). There is thus a need to quantify the carbon footprint of differently managed lawns, for which SOC is of major importance. In the transdisciplinary Swedish LAWN project (http://www.slu.se/lawn), lawns were studied from social, ecological, and aesthetic perspectives (Ignatieva et al., 2015).

In this study, as part of the LAWN project, we analysed two types of lawn under different management intensity (cutting frequency) associated with multi-family housing areas which were intensively monitored at three sites in each of three Swedish cities. The objectives of the study were (i) to examine how cutting frequency affected NPP, SOC, and soil carbon to nitrogen ratio (C : N) and (ii) to reveal involved mechanisms causing differences in SOC between the two management regimes.

2 Materials and methods

2.1 Study sites

Public lawns in multi-family housing areas were investigated in three different cities – Gothenburg, Malmö, and Uppsala – and at three different sites in each city (Table 1). The nine selected multi-family housing areas were established at approximately the same time during the early 1950s. At each site, triplicate plots of two different lawn types were studied: utility lawn and meadow-like lawn, with each plot comprising one complete lawn. The utility lawn was kept short during the year and was mown on average every 18 days within the mowing period (eight times), which approximately corresponds with the growing period (May to mid-October in Uppsala, and April to late October in Gothenburg and Malmö). The meadow-like lawns were only cut once, or twice in the single case of one lawn in Uppsala (Tuna Backar). Grass cuttings were left on the surface on both lawn types. None of the lawns received any fertiliser. Grass species composition did not differ greatly between the cities, with about 5–10 different grass species abundant in utility lawns and meadow-like lawns. Utility lawns consisted of sparser, low-growing species such as *Poa annua*, *Agrostis capillaris*, *Lolium* spp., and *Festuca rubra*, while the most abundant grass species in meadow-like lawns were *Phleum pratense*, *Alopecurus pratensis*, and *Arrhenatherum* spp. (J. Wissman, personal communication, 2015). The size of the individual lawns was highly unequal with a range of 0.05–2.5 ha due to the heterogeneity of urban landscapes. To obtain representative average values for the whole individual lawn, we conducted all samplings described below adjusted to the size of the lawn, instead of using a “fixed grid”.

Table 1. Site characterisation with year of establishment; mean annual temperature [MAT, °C] and mean annual precipitation [MAP, mm] (1961–1990); and clay, silt, and sand content [%] as well as soil pH for utility lawns (U) and meadow-like lawns (M) for all three Swedish cities studied.

City	Site	Age	MAT	MAP	C : N	Clay		Silt		Sand		pH*	
						U	M	U	M	U	M	U	M
Uppsala	Eriksberg	1949	5.5	527	12.8	36	46	43	44	21	10	∼ 6	∼ 6
	Sala Backe	1950			12.5	45	45	47	51	8	4	∼ 6	∼ 6
	Tuna Backar	1951			13.1	33	23	47	45	20	32	∼ 6	∼ 6
Malmö	Kirseberg	1950	8.4	540	12.7	12	10	49	46	39	45	7.2	7.2
	Sibbarp	1953			13.8	15	15	48	47	38	38	7.4	7.8
	Augustenborg	1952			13.9	13	10	49	45	38	45	7.4	7.7
Gothenburg	Guldheden	1950[a]	7.4	714	14.1	16	14	45	44	39	42	5.5	5.4
	Kyrkbyn	1955			12.0	16	22	62	55	21	23	5.8	5.7
	Björkekärr	1950[a]			12.8	14	16	49	58	37	27	5.5	5.7

[a] year only approximate. * pH values for the Uppsala sites were not measured, and the values shown are estimates based on typical values for soils in Uppsala (e.g. Kätterer et al., 2011).

2.2 Estimation of aboveground net primary production and root biomass

Aboveground NPP in the utility lawns was estimated by repeated sampling of aboveground biomass after the first mowing in spring by the local authority. Sampling was conducted on average 12 ± 6 days after each mowing event. For the meadow-like lawns, biomass was collected on several occasions even before the mowing to determine total growth at that specific time. After the first cut, meadow-like lawns were treated as utility lawns. The plots were sampled at four locations using a 50 cm × 50 cm square frame. Sampling locations were selected to be representative of the total lawn area, so therefore sampling under trees or in proximity to other vegetation was avoided. Repeated sampling was not conducted on the identical sampling locations. The harvested biomass was dried at 70 °C, weighed, and multiplied by 4 to obtain the biomass for 1 m^2. The mean of the four replicates was divided by the number of days between the last cutting and sampling to obtain daily growth rate. This growth rate was extrapolated to cover all days between previous sampling and next mowing for which no growth rate was determined. On average, this period accounted for 7 ± 6 days after each cutting event, and thus data coverage (time for which the actual growth rate was measured) was more than 82 ± 6 % for the period between 1 January and the last sampling date, which was on average on 5 October ±7 days. On the basis of these daily growth rates, we calculated cumulative growth until the last sampling. Since this day varied slightly between plots and sites, we fitted a simple vegetation model based solely on the plant response to air temperature, as developed by Yan and Hunt (1999) to each growth curve in order to determine the regrowth after the last sampling until the end of the vegetation period. The original equation is

$$r = R_{\max}\left(\frac{T_{\max}-T}{T_{\max}-T_{\mathrm{opt}}}\right)\left(\frac{T}{T_{\mathrm{opt}}}\right)^{\frac{T_{\mathrm{opt}}}{T_{\max}-T_{\mathrm{opt}}}}, \quad (1)$$

where r is the daily rate of plant growth, T is the measured temperature at any day, $T_{\max}$ is the maximum temperature (which was set to 30 °C in this study), T_{opt} is the optimal temperature (which was set to 25 °C in this study), and $R_{\max}$ is the maximal growth rate at T_{opt}. Instead of using $R_{\max}$, which is used in Eq. (1) to scale the temperature response function to actual observed maximal plant growth at optimal temperature, we scaled the model by forcing the cumulated r through the cumulated NPP value on the date of the last sampling, as illustrated in Fig. 1 using the example of the Björkekärr site in Gothenburg. The good fit indicates that (i) the growth dynamics, and thus absolute growth, were well captured by the method used and (ii) the model fits provide an unbiased and standardised extrapolation of aboveground NPP for the entire growing period. Daily mean air temperature values for the closest weather stations of the Swedish Meteorological Service (SMHI) to Malmö and Gothenburg were downloaded from http://www.smhi.se/klimatdata. Daily average air temperature values for Uppsala were obtained from the Ultuna climate station run by the Swedish University of Agricultural Sciences (SLU).

Root biomass was only determined once, and only in Uppsala. In each lawn, four cylindrical soil cores of 7 cm diameter and 10 cm depth were taken at 0–10 cm soil depth. Aboveground plant material was removed and soil cores were thoroughly rinsed and then put in a water bucket to completely separate roots from soil. Roots were dried at 105 °C weighed and analysed for carbon (C) and nitrogen (N) content. Assuming a carbon content of 45 % for plant biomass, we were able to determine and subtract the adhering soil in the weighed root samples mathematically, as described in Janzen et al. (2002).

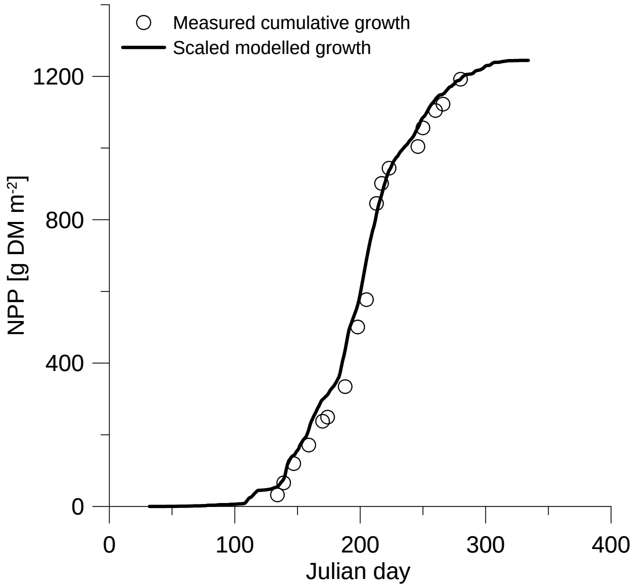

Figure 1. Example of the vegetation model (Eq. 1) fit to a calculated cumulative growth curve for a utility lawn in Björkekärr, Gothenburg.

2.3 Soil sampling, analysis, and SOC stock calculation

Soils were sampled in autumn 2014 to a depth of 20 cm using an auger (2.2 cm diameter). In each plot, 10 randomly distributed soil cores were taken and pooled to one composite sample. Soils were dried at 40 °C, sieved to 2 mm, and visible roots were manually removed. Soil pH was determined in water and samples with a pH value exceeding 6.7 were analysed for carbonates. Soil texture was determined with the pipette method according to ISO 11277. As a slight modification, wet sieving prior to sedimentation was done to 0.2 mm compared to 0.063 mm prescribed in the ISO method. Total soil carbon and nitrogen were determined by dry combustion of 1 g of soil using a LECO TruMac CN analyser (St. Joseph, MI, USA) and carbonate carbon was determined using the same instrument after pretreatment overnight at 550 °C. Organic soil carbon was calculated as the difference between total carbon and carbonate carbon. Soil bulk density [g cm^{-3}] was determined by taking undisturbed cylindrical soil cores of 7 cm diameter and 10 cm height in an approximate soil depth of 5–15 cm, drying them at 105 °C, and weighing them. Four samples were taken in each plot. To account for the fact that SOC stocks under contrasting management regimes should be compared on the basis of equivalent soil masses (Ellert and Bettany, 1995), we conducted a simple mass correction in which we first calculated the soil mass (SM) [Mg ha^{-1}] of each plot using the equation

$$\mathrm{SM} = \mathrm{BD} \times D \times 100, \tag{2}$$

where BD is the soil bulk density [g cm^{-3}] and D is the sampling depth [cm]. The lower average soil mass measured at each pair was then used as the reference soil mass (RSM) to which the other treatment of each pair (three pairs per site) were adjusted.

SOC stocks [Mg ha^{-1}] were then calculated using the equation:

$$\mathrm{SOCstock} = \mathrm{RSM} \times \frac{C}{100} \tag{3}$$

where C is carbon concentration [%]. At one site in Gothenburg (Kyrkbyn), one pair of lawn types had a large difference in soil texture, with 15 % clay in the utility lawn and 30 % in the meadow-like lawn. The SOC concentration varied by a similar amount (2.46 % compared with 4.58 %), which was an outlying high difference when compared with that of all other pairs. We attributed this to differences in soil texture and excluded this pair from the analysis. Apart from slight differences in soil texture, the basic assumption was that the underlying pedology and initial soil carbon stocks were similar for both lawn types, or at least not systematically biased. Differences in soil texture between lawn types at each site was further not correlated to differences in SOC concentration ($R^2 = 0.02$).

2.4 Statistics

All statistical analyses were performed with R software version 3.1.2. We used linear mixed effect models to analyse the effect of lawn management on aboveground NPP and SOC concentration and stocks using the R package nlme (Pinheiro et al., 2009). Management (utility vs. meadow-like lawn) was used as the fixed effect, while city and site were used as nested random effects (site nested in city). We used Tukey-type multiple comparison post hoc analysis (R package multcomp) to test the management effect at each site for significance ($p < 0.05$). Average differences in SOC stocks between the different lawn types at each site (dependant variable) were calculated and related to different explanatory variables (independent variables), such as average clay content, differences in clay content between lawn types (absolute and relative), soil pH, mean annual temperature (MAT), mean annual precipitation (MAP), and differences in aboveground NPP. Generalised linear models with Gaussian error distribution were used for multiple regression analysis. Model performance was evaluated using the Akaike information criterion (AIC). The variable “clay content” had to be transformed to approximate normal distribution. For both model approaches (mixed effect model and generalized linear model) we used residual plots to study whether (i) the regression function was linear, (ii) the error terms had constant variance, (iii) the error terms were independent, (iv) there were outliers, or (v) the error terms were normally distributed. All values in the text and diagrams represent mean ± standard deviation.

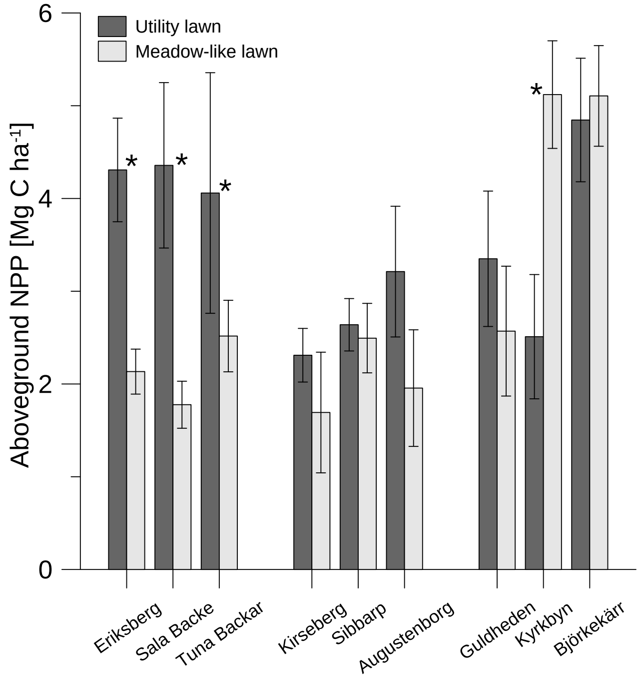

Figure 2. Bar plot showing estimated aboveground net primary production (NPP) of the two different lawn types at each site. Error bars indicate standard deviation and stars indicate significant difference between treatments at the specific site ($p < 0.05$).

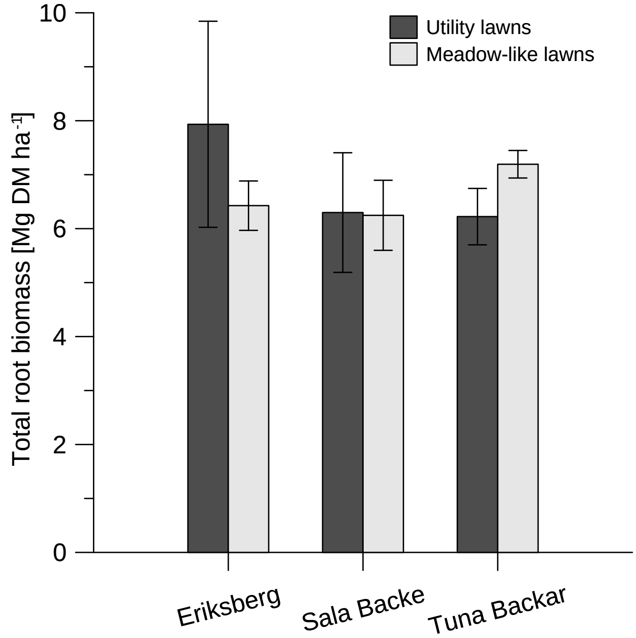

Figure 3. Bar plot showing total root biomass at 0–10 cm depth for the two different lawn types at the study sites in Uppsala. Error bars indicate standard deviation.

3 Results

Effect of lawn management on net primary production and soil carbon and nitrogen

The intensively managed, i.e. frequently mown, utility lawns produced significantly ($p = 0.003$) more aboveground biomass (NPP) than the meadow-like lawns, which were cut only once a year (Fig. 2). At seven out of nine sites, NPP was higher in the utility lawns than in the meadow-like lawns. The difference between the lawn types was most pronounced in Uppsala, where the average NPP of the utility lawns (4.2 ± 0.9 Mg C ha^{-1}) was twice that of the meadow-like lawns (2.1 ± 0.3). In contrast, two out of three sites in Gothenburg showed higher NPP on the meadow-like lawns. Across all sites, the NPP of the utility lawns was 24 % higher. Total root biomass, as investigated at the three sites in Uppsala, was not significantly influenced by management intensity and indicated a smaller ratio of belowground to aboveground NPP in meadow-like lawns (Fig. 3).

Concentrations of SOC were also positively affected by greater cutting frequency. Utility lawns had significantly higher ($p = 0.01$) SOC concentration than meadow-like lawns (Fig. 4). Again, the difference between the two lawn types was most pronounced in Uppsala, with an average SOC concentration of 3.9 ± 0.6 % in the utility lawns and 2.9 ± 0.9 % in the meadow-like lawns. In both Malmö and Gothenburg, we found one site with higher average SOC concentration in the meadow-like lawns. The calculated SOC stocks are listed in Table 2. The average SOC stock difference between the two differently managed lawn types was 7.8 Mg ha^{-1} or 12 %. The very similar patterns observed for the variables NPP and SOC suggest that the SOC changes were driven by NPP and thus carbon input. In fact, the difference in SOC stock between management regimes at each site was significantly correlated to the difference in NPP (Fig. 5). No other parameter added significant explanation to the model fit. Although clay content did not improve the model fit of the generalized linear model, difference in SOC stock also increased with average clay content ($R^2 = 0.26$, $p = 0.1$, not shown). This correlation is, however, strongly driven by the sites in Uppsala, which showed the highest increase in both NPP and SOC. Thus, local management differences, which are, however, not available in detail, might also have influenced the observed treatment effect on SOC to some degree.

The soil C : N ratio of the meadow-like lawns (13.2 ± 1.2) was significantly higher ($p = 0.007$) than that of the utility lawns (12.6 ± 0.7), indicating that the soil organic matter under the utility lawns was relatively enriched in nitrogen (Fig. 6).

Table 2. Soil bulk density (BD) [$g\,cm^{-3}$] and SOC stocks [$Mg\,ha^{-1}$] according to Eq. (3). Standard deviation is given in brackets.

City	Site	Utility lawn BD		Meadow-like lawn BD		Utility lawn SOC stock		Meadow-like lawn SOC stock	
Uppsala	Eriksberg	1.13	(0.04)	1.13	(0.16)	74.8	(11.4)	63.1	(8.7)
	Sala Backe	1.14	(0.03)	1.1	(0.07)	96.2	(9.3)	69.8	(24.2)
	Tuna Backar	1.15	(0.07)	1.21	(0.06)	72.4	(13.3)	47.6	(19.5)
Malmö	Kirseberg	1.03	(0.07)	1.02	(0.08)	69.4	(4.5)	52.7	(0.95)
	Sibbarp	1.04	(0.06)	0.98	(0.06)	75	(8.3)	96.4	(3.5)
	Augustenborg	1.03	(0.06)	1.18	(0.15)	59.1	(9.4)	50.3	(22.4)
Gothenburg	Guldhelden	0.87	(0.14)	0.88	(0.21)	86.2	(2.3)	78.4	(21.3)
	Kyrkbyn	0.99	(0.09)	0.88	(0.06)	68.2	(8.1)	77.9	(7.8)
	Björkekärr	0.96	(0.1)	0.99	(0.08)	67	(14.4)	61.2	(3.1)

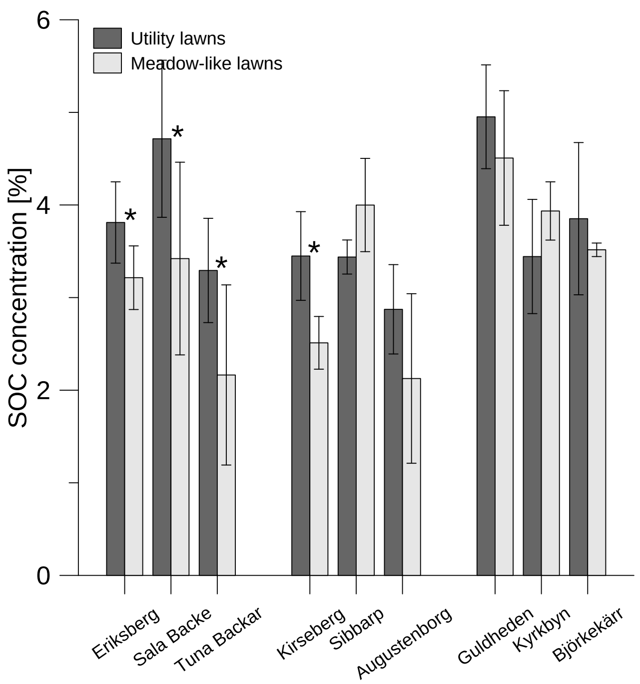

Figure 4. Bar plot showing measured soil organic carbon (SOC) concentration in the two different lawn types at each site. Error bars indicate standard deviation and stars indicate significant difference between treatments at the specific site ($p < 0.05$).

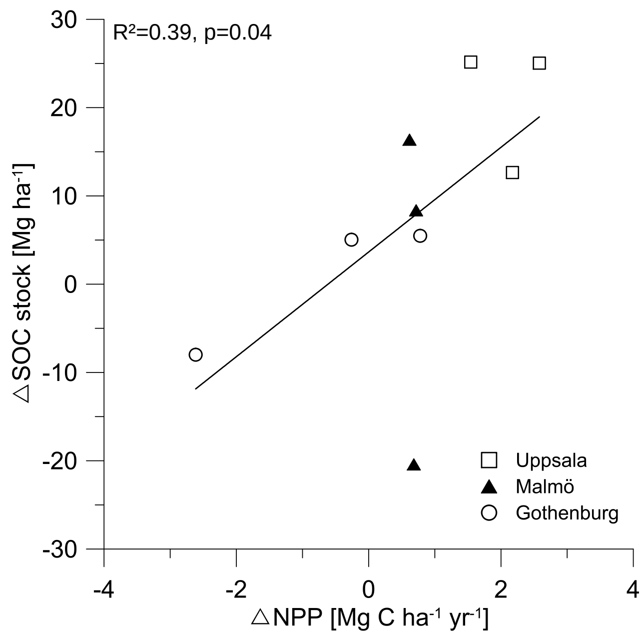

Figure 5. Difference in soil organic carbon (SOC) stock between utility and meadow-like lawns as a function of difference in aboveground NPP for all sites.

4 Discussion

4.1 Effect of cutting frequency on aboveground productivity

We showed that cutting frequency significantly altered the aboveground biomass production in urban lawns. This can be explained by the fact that canopy CO_2 assimilation is a function of the amount of assimilating plant matter (Wohlfahrt et al., 2008). Wohlfahrt et al. (2008) showed that when the green area index (GAI) of an alpine grassland exceeded $4\,m^2\,m^{-2}$, the gross primary production (GPP) decreased due to shading, but also due to plant phenology. Directly after cutting (three cuts per season), their grassland had a GAI of 0.5–2 $m^2\,m^{-2}$, while directly before cutting it had a GAI $> 6\,m^2\,m^{-2}$. The meadow-like lawns in our study were only cut once, which indicates that the period in which the GAI of the canopy exceeded the optimum for CO_2 assimilation was very long. In contrast, the GAI of the utility lawn remained relatively close to the optimum throughout the entire growing period. Furthermore, Klimeš and Klimešová (2002) found that frequent mowing promoted the dominance of efficiently regrowing plant species, which might provide an additional explanation for the higher NPP in our util-

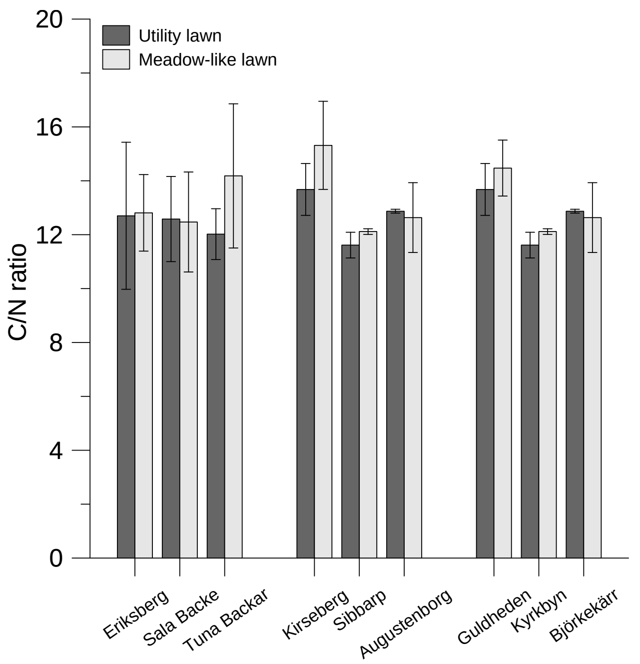

Figure 6. Bar plot showing measured C : N ratio of the two different lawn types at each site. Error bars indicate standard deviation.

ity lawns. Our results are also in agreement with Kaye et al. (2005), who found 5-fold higher aboveground NPP in an urban lawn than in a short-grass steppe. However, the urban lawn in that study was fertilised and irrigated, while the urban lawns in our study were not. In a long-term field experiment on cutting frequency effects on grass yield, Kramberger et al. (2015) found the lowest yield in plots with the highest cutting frequency (2-week intervals) and the highest yield in plots with moderate to low cutting frequency (8- to 12-week intervals). This is in contrast to our results from Uppsala and Malmö, but in line with the results from Gothenburg, where we found higher aboveground biomass in the meadow-like lawns. However, we are unable to explain the much higher NPP of the meadow-like lawns in Kyrkbyn.

4.2 Effect of cutting frequency on soil organic carbon in relation to similar management contrasts

The higher aboveground NPP in the utility lawns had a significant positive effect on soil carbon. This was expected, since the clippings were not removed and were thus able to contribute directly to soil organic matter formation. For this reason, the results of our study are not directly applicable to mown grasslands or leys, which are usually harvested. The responses of SOC to management intensity in those systems are not well studied, but studies performed to date show mixed results ranging from no effect (Kramberger et al., 2015) to significantly positive effects of high cutting frequency (Ammann et al., 2007). In the latter case, the difference in SOC stocks between intensively and extensively managed grassland was attributed to differences in N fertilisation, which caused N deficiency and thus N mining in the extensive grassland, leading to stronger mineralisation of stable organic matter. The effects of grazing intensity on SOC are much better studied than the effects of mowing intensity. Both positive (Reeder et al., 2004; Smoliak et al., 1972) and negative (Abril and Bucher, 2001; Su et al., 2005) effects of low compared with high grazing intensity on SOC have been reported. However, many of the studies reporting negative effects of intensive grazing refer to overgrazing in semiarid areas, which is associated with strongly reduced vegetation cover and soil erosion. The actual effects seem to be context-specific, as found in a global meta-analysis conducted by McSherry and Ritchie (2013). The found positive correlation of difference in SOC and average clay content across sites has to be interpreted with caveats, since a clear causality is not given. It is realistic that more of the C input is stabilised in clay-rich soils (Poeplau et al., 2015b). However, this correlation did not hold within the three sites at each city, which indicates that the correlation found of clay and difference in SOC, as well as of clay and difference in NPP, across all sites might also resemble a random city effect.

Overall, our findings and those of previous studies (Christopher and Lal, 2007; Poeplau et al., 2015a) confirm that plant input driven by NPP is the major driver for SOC dynamics. Root carbon input is recognised as being of major importance for building up soil organic matter, since a higher fraction of root-derived carbon is stabilised in the soil than in aboveground plant material (Kätterer et al., 2011). In temperate grasslands, up to 70 % of the total NPP is allocated to roots and their exudates (Bolinder et al., 2007). However, in the present study, management intensity did not significantly influence root biomass, indicating that root production was relatively favoured in the meadow-like lawns. A similar finding has been reported in a study which found higher root biomass under diverse swards than under conventional, intensively managed ryegrass-clover pastures (McNally et al., 2015). Altered root production could therefore not explain observed differences in SOC stocks in our study. However, the informative value of the obtained root data is certainly limited, since root biomass was only determined in one city, to a depth of 10 cm and at one point in time. It can thus not be assumed that the measured root biomass measured is representative of root growth throughout the season (Ziter and MacDougall, 2013). Furthermore, potential management effects on the depth distribution of belowground biomass cannot be inferred.

The proportion of aboveground plant material stabilised in the soil has been estimated to be 13 % in a Swedish long-term agricultural field experiment (Andrén and Kätterer, 1997). Similar values, i.e. around 10 %, have been reported in other studies (Lehtinen et al., 2014; Poeplau et al., 2015b). It can be assumed that lawn clippings undergo slightly lower stabilisation than straw in agricultural systems, due to the lack of mixing of residues with stabilising mineral soil particles (Wiesmeier et al., 2014). The mean annual difference in SOC sequestration between the two lawn types we studied was 120 kg C ha^{-1} yr^{-1}. Assuming a constant stabilisation rate of 10 % across all sites, the calculated difference in SOC sequestration due only to different amounts of recycled clippings would have been 69 kg C ha^{-1} yr^{-1}, which is only slightly more than half the observed difference. Several studies report accelerated root turnover in more intensively managed grassland (Klumpp et al., 2009; Leifeld et al., 2015). However, accelerated root turnover could result in either more or less root-derived SOC, depending on the effect on total root growth and exudations throughout the year, which is difficult to investigate (Johnen and Sauerbeck, 1977).

Interestingly, the soil C : N ratio was significantly lower in the utility lawns than in the meadow-like lawns, although neither system was fertilised and both were equally exposed to N deposition. Furthermore, the proportion of N-fixing leguminous plants was higher in the utility lawns than in the meadow-like lawns only in Gothenburg. This might indicate that nitrogen cycling was more closed in the utility lawns. Potentially, more nitrogen is lost via leaching in the meadow-like lawns, because N mineralisation and plant N demand occur asynchronously (Dahlin et al., 2005). The peak in N mineralisation usually occurs around midsummer (Paz-Ferreiro et al., 2012), which might be too late for plant uptake when the grass is not mown and would lead to N losses from the system. Another pathway of N loss is ammonia (NH_3) volatilisation, which increases in later development stages of the plant due to ontogenetic changes in plant N metabolism (Morgan and Parton, 1989). Whitehead and Lockyer (1989) showed 10 % N losses from decomposing grass herbage by NH_3 volatilisation. The consequences of N deficiency for SOC dynamics are twofold: (i) decreased NPP and thus decreased carbon input (Christopher and Lal, 2007) and (ii) increased heterotrophic respiration due to N mining in more recalcitrant organic matter (Ammann et al., 2007). In an incubation experiment, Kirkby et al. (2014) showed that more aboveground residues were stabilised in the soil when nitrogen was added. Thus, negative effects of lawn management on soil N storage can feed back onto SOC, which might also explain a certain proportion of the observed differences in SOC.

4.3 Implications for urban soil management

During the past decade, several studies have investigated biogeochemical cycles in urban soils, since their relevance for the global carbon cycle and as a fundamental ecological asset in an urbanising world is becoming increasingly evident (Lehmann and Stahr, 2007; Lorenz and Lal, 2009). Compared with data on agricultural land with similarly textured soils in the surroundings of the study sites extracted from a national soil inventory database, we found on average 55 % (utility lawns) and 35 % (meadow-like lawns) higher SOC stocks in the lawns we investigated. Furthermore, it has been found in several studies that urban soils have higher carbon stocks than native soils in adjacent rural areas, which can be attributed in particular to more optimised, but also resource-consuming, management, including fertilisation and irrigation (Edmondson et al., 2012; Kaye et al., 2005; Pouyat et al., 2009). However, in the present study we were able to show that SOC storage in urban lawns can be increased at comparatively low cost under temperate climate conditions by optimising NPP and leaving residues on the lawn. Losses of carbon and nutrients are thereby minimised. Milesi et al. (2005) used the BIOME-BGC model to compare different lawn management scenarios and found that applying 73 kg N and recycling the clippings was more efficient for SOC sequestration (+40 %) than applying 146 kg N and removing the clippings. For the sites in Uppsala, Wesström (2015) calculated that the management of utility lawns creates 54 kg ha^{-1} yr^{-1} more C emissions than the management of meadow-like lawns. With this value subtracted from the annual difference in SOC sequestration that we found (120 kg C ha^{-1} yr^{-1}), the utility lawns in our study sequester a non-significant amount of 66 kg ha^{-1} yr^{-1} more carbon than the meadow-like lawns. However, for a full greenhouse gas budget, the effects of lawn management on other trace gases, primarily nitrous oxide (N_2O), have to be considered (Townsend-Small and Czimczik, 2010). In that case, management of the clippings will most likely play a key role, since coverage of the soil with organic material increases soil moisture and the availability of labile carbon but decreases soil oxygen, all of which favour N_2O formation (Larsson et al., 1998; Petersen et al., 2011).

5 Conclusions

This investigation of urban lawns in three Swedish cities showed that cutting frequency alone can exert a significant influence on soil carbon, mainly by increasing net primary production and thus carbon inputs. However, this is most likely only true when cuttings are left on the lawn, since belowground production did not show any differential response to cutting frequency. Moreover, the observed difference in soil carbon could not be fully explained by the expected stabilisation of aboveground-derived carbon input differences, which might denote that either root-derived carbon dynamics or nitrogen mining also play an important role. If clippings are left on the lawn, nitrous oxide emissions might comprise a significant fraction of the greenhouse gas budget of lawns and have to be accounted for to judge the climate mitigation potential of contrasting lawn or grassland management strategies.

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Energy use and greenhouse gas emissions from turf management of two Swedish golf courses

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ABSTRACT

Turf management on golf courses entails frequent maintenance activities, such as mowing, irrigation and fertilisation, and relies on purchased inputs for optimal performance and aesthetic quality. Using life cycle assessment (LCA) methodology, this study evaluated energy use and greenhouse gas (GHG) emissions from management of two Swedish golf courses, divided into green, tee, fairway and rough, and identified options for improved management. Energy use and GHG emissions per unit area were highest for greens, followed by tees, fairways and roughs. However, when considering the entire golf course, both energy use and GHG emissions were mainly related to fairway and rough maintenance due to their larger area. Emissions of GHG for the two golf courses were 1.0 and 1.6 Mg CO_2e ha^{-1} $year^{-1}$ as an area-weighted average, while the energy use was 14 and 19 GJ ha^{-1} $year^{-1}$. Mowing was the most energy-consuming activity, contributing 21 and 27% of the primary energy use for the two golf courses. In addition, irrigation and manufacturing of mineral fertiliser and machinery resulted in considerable energy use. Mowing and emissions associated with fertilisation (manufacturing of N fertiliser and soil emissions of N_2O occurring after application) contributed most to GHG emissions. Including the estimated mean annual soil C sequestration rate for fairway and rough in the assessment considerably reduced the carbon footprint for fairway and turned the rough into a sink for GHG. Emissions of N_2O from decomposition of grass clippings may be a potential hotspot for GHG emissions, but the high spatial and temporal variability of values reported in the literature makes it difficult to estimate these emissions for specific management regimes. Lowering the application rate of N mineral fertiliser, particularly on fairways, should be a high priority for golf courses trying to reduce their carbon footprint. However, measures must be adapted to the prevailing conditions at the specific golf course and the requirements set by golfers.

1. Introduction

Mitigation of climate change and reducing the current dependency on fossil fuels are interlinked challenges shaping policies in many sectors. The European Union (EU) has committed itself to reducing greenhouse gas (GHG) emissions, increasing the share of renewable energy supply and improving energy efficiency, all by 20% by 2020 (European Commission, 2007), and this commitment requires immediate measures in all sectors of society.

There are more than 500 golf courses, occupying approximately 28,000 ha, in Sweden (Statistics Sweden, 2013). Golf is associated with several benefits, e.g. it provides recreational value for the many people who play the game, enhances local biodiversity through extensively managed roughs in areas with intensively managed agriculture (Tanner and Gange, 2005) and promotes soil carbon (C) sequestration (Qian and Follett, 2002; Selhorst and Lal, 2011). Managed turfgrass systems achieve significantly higher C sequestration than arable land and extensively managed grassland (Qian and Follett, 2012). However, turfgrass maintenance on golf courses is reliant on repeated mowing, which requires fossil energy and releases GHG emissions to the atmosphere, mainly as carbon dioxide (CO_2). High turfgrass quality also requires other maintenance practices such as irrigation, fertilisation, vertical cutting, aeration and sand dressing, all with associated environmental impacts. Furthermore, nitrogen (N) from fertilisers and plant residues enhances nitrification and denitrification, which may increase emissions of nitrous oxide (N_2O). Intensive turfgrass management combining frequent irrigation and fertilisation can

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enhance N_2O losses, particularly if water is applied immediately after fertilisation (Gu et al., 2015). However, soil N_2O production is associated with high variability depending on soil properties and management, which poses a great challenge when estimating N_2O emissions (Li et al., 2013). Emissions of N_2O are particularly worrisome since N_2O is a potent greenhouse gas with high global warming potential (GWP). The GWP of a certain gas is a measure of how much heat is trapped in the atmosphere relative to the amount of heat trapped by CO_2 over a specific time interval (IPCC, 2007). The concept of GWP for different GHG makes it possible to add them together to obtain total GWP for an entire system.

Energy use and GHG emissions are not only associated with the maintenance activities performed on the golf courses, since there are also indirect environmental burdens related to production of purchased inputs such as mineral fertilisers, fuel, machinery and transport of sand used for dressing. Life cycle assessment (LCA) is a comprehensive methodology addressing both direct and indirect energy use and emissions along the entire value chain in order to identify environmental hotspots. LCA is a commonly used standardised procedure for identifying opportunities for improved environmental performance and providing decision support for stakeholders in strategic planning and development (ISO, 2006). Carbon footprinting, a subset of a full LCA including only GHG emissions caused by a product or a service during its life cycle and summarised as CO_2-equivalents, is attracting increasing interest in the context of global warming mitigation (Röös, 2013).

A number of studies have evaluated GHG emissions from public and private lawns (e.g. Townsend-Small and Czimczik, 2010; Zirkle et al., 2011; Selhorst and Lal, 2013; Kong et al., 2014; Gu et al., 2015), while fewer studies are available for golf courses. Bartlett and James (2011) modelled GHG emissions from two golf courses in the UK and determined the balance between soil C sequestration and emissions from turf management. They assumed the same sequestration rate for the treeless components of the golf courses (green, tee, fairway and rough), independent of time since construction, mowing frequency and fertilisation rate, and found that the main contribution to GHG emissions came from mowing and production of fertilisers. Selhorst and Lal (2011) included C release due to different maintenance practices, summarised for the entire golf course, but excluded GHG emissions other than CO_2.

Depending on the prevailing climatic and edaphic conditions, turf management differs between locations. In addition, the different playable areas on a golf course are managed with differing intensity. In order to devise and implement efficient and well-adjusted measures for sustainable turf management, more knowledge is required about current energy use and GHG emissions from different components of the golf course and how these are distributed among different management activities.

The objective of the present study was thus to evaluate energy use and GHG emissions from annual management of two Swedish golf courses divided into green, tee, fairway and rough, and identify options for improved management. Particular emphasis was placed on maintenance operations and purchased inputs.

2. Material and methods

LCA methodology was used for evaluation of primary energy use and GHG emissions associated with turf management on golf courses during one year. Emissions of GHG were summarised as CO_2-equivalents (CO_2e) according to IPCC (2007), with a time horizon of 100 years. The results were presented both per hectare and for the entire courses.

Information on management practices was obtained through interviews with course managers of the golf courses. A brief description of different activities performed on the two golf courses is presented below, while a more detailed description can be found in Wesström (2015).

Table 1
Area of the different playable components included in the study, based on information provided by the golf course managers.

Course	Green (ha)	Tee (ha)	Fairway (ha)	Mowed rough (ha)	Total (ha)
Sigtuna	1.5	1.0	10	40	52.5
Uppsala	2.5	1.5	22	50	76

2.1. Description of the golf courses and their management

The golf courses included in the study are parkland courses situated in eastern Sweden. One of the golf clubs is located in the county of Uppsala and was established at its present site in 1964. It currently consists of one 18-hole course and two 9-hole courses, with a total playable area of 76 ha (Table 1). The other golf club is located outside the town Sigtuna, in between Stockholm and Uppsala. It has one 18-hole course constructed in the end of the 1960s, one 6-hole course and four practice greens. The golf courses are surrounded by a mosaic landscape characterised by agricultural land and forest. The total playable areas of the courses in Sigtuna and Uppsala were 52.5 and 76 ha, respectively (Table 1).

The golf season is approximately 26 weeks in Uppsala and 28 weeks in Sigtuna. Maintenance strategies differ considerably between the playing areas, in order to provide optimal performance and aesthetic quality for each specific area.

2.2. Application of fertiliser, pesticides, sand and water

The application rate of mineral fertilisers varies slightly between years. Sigtuna follows a specific fertiliser regime where the weekly fertilisation of greens and tees is pre-ordained. Here, we used data from 2013, which was considered to be a representative year. At Uppsala, fertiliser application is determined by the course manager and the data used in this study were representative of recent years. Fertilisers are applied manually to greens and tees on a regular basis throughout the season. Fairways are fertilised mechanically several times a year, while roughs do not receive any mineral fertiliser.

Fungicides and herbicides are occasionally used at both courses, while insecticides are not used at all. The rough in Uppsala receives herbicides once every other year.

The irrigation frequency is determined by precipitation. In general, greens, tees and fairways are irrigated approximately three times per week, while roughs are not irrigated at all. The irrigation water used in Sigtuna is pumped from a nearby lake and distributed via an underground pipe system, complemented with a hose when necessary. In Uppsala, the water is pumped from a nearby pond that also receives drainage water from the course. The amounts of water applied to the different parts of the course in this study were based on estimates by the managers, since no measured data were available. Sand for dressing is applied on greens and tees at both sites, and on fairways in Uppsala. This sand is transported 160 km to Uppsala and 50 km to Sigtuna. The amounts of mineral fertiliser, sand and pesticides applied and the volume of water used for irrigation are presented in Table 2.

2.3. Mowing and other maintenance practices

Greens are mowed seven times a week at Uppsala and five to six times a week at Sigtuna during the season. Tees and fairways are mowed three times a week at both sites during the season. Roughs are mowed once a week during the season, using a rotary mower. On all areas, seasonal mowing is complemented with some additional off-season mowing. The grass clippings from greens and tees

Table 2
Annual amounts of mineral fertilisers (N, P and K), sand, pesticides (active substance) and irrigation water applied per hectare to different parts of the golf courses in Sigtuna and Uppsala.

	Site	N (kg)	P (kg)	K (kg)	Pesticide (kg)	Sand (Mg)	Irrigation (10^3 m^3)
Green	Sigtuna	214	37	139	1.35	187	3.6
	Uppsala	190	80	190	1.35	120	3.0
Tee	Sigtuna	176	27	108		40	3.6
	Uppsala	220	40	220	1.35	33	3.0
Fairway	Sigtuna	89	12	40	0.39		1.8
	Uppsala	160	40	160	0.64	30	1.4

are collected by the mower at both sites and are either composted or spread out on other grass-covered areas. Clippings from fairways and roughs are not collected, but left on-site.

Aeration is performed with different frequency and machinery on different parts of the golf course. Deep-tine aeration and hole pipe aeration are mainly used on greens and tees. Verticutting is performed on greens at both sites, but only on tees at Sigtuna. Topdressing is most frequently used on greens. The seasonal management practices performed are summarised in Table 3.

In Sigtuna, 150 L of engine oil and 160 L of hydraulic oil are used annually for maintenance of the machinery, while the corresponding values in Uppsala are 60 and 150 L, respectively.

Mean fuel consumption for different operations is summarised in Table 4. All machinery was assumed to use diesel except for a pedestrian mower for greens and a walk-behind aerator for aeration of greens and tees, which consumed petrol. Data on mowing of greens and fairways in Uppsala were obtained from a previous study of fuel consumption per cycle of maintenance on the main golf course (Caple, 2008), while the course manager provided estimates for mowing in Sigtuna. No measurements were available for mowing the rough in Uppsala and therefore the estimated fuel consumption per occasion (6 L ha^{-1}) at Sigtuna was also used for Uppsala. Fuel consumption for aeration was based on assumptions made by the golf course managers. The difference in assumed fuel consumption was due to different machinery being used for aeration. Data on fuel consumption for verticutting and dressing were based on measurements (Caple, 2008). Since a higher rate of sand was applied to tees and fairways in Uppsala, higher fuel consumption per hectare was assumed for these areas compared with dressing of the greens, based on estimates made by the course managers.

2.4. System boundaries

The system studied included production of purchased inputs (fertiliser, fuel and electricity), transport of sand, production, maintenance and repair of machinery, and turf management for different activities according to current practices during one representative year (Fig. 1). Fuel consumption per maintenance cycle included travelling between courses parts for the machinery in use.

The contribution from production and application of herbicides and fungicides was omitted in the assessment, since it contributed less than 1% to the total energy use and GHG emissions. Reseeding was also omitted, since its contribution was considered negligible.

Construction of the courses was not included due to lack of information about the resources used during construction, as it was performed many decades ago.

A considerable amount of clippings is either composted, spread out directly on other grassed areas or left on-site after mowing. The emissions of N_2O associated with turnover of these clippings were considered in the sensitivity analysis, since high variability can be expected and no measurements were available. Indirect emissions of N_2O caused by N losses through volatilisation and leaching were not accounted for, since these emissions were considered minor compared with the direct emissions of N_2O.

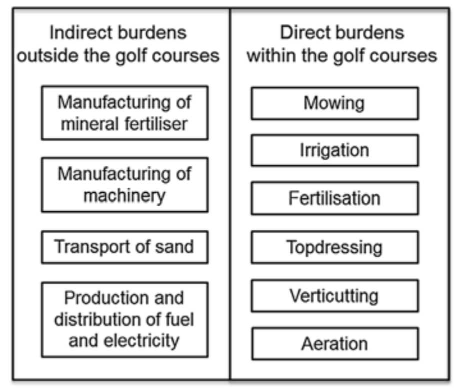

Fig. 1. Activities included in the study causing direct and indirect energy use and GHG emissions within and outside the golf courses.

2.5. General assumptions and data used

Data on GHG emissions from fuel combustion relating to transport and maintenance operations were taken from Gode et al. (2011) and included production, distribution and combustion. Only emissions data for standard diesel were used, although also synthetic diesel was used for some applications. Electricity consumption for irrigation was estimated by the course managers to be 0.45 kWh m^{-3} at Uppsala and 0.5 kWh m^{-3} at Sigtuna. Emissions data for the Swedish average electricity production were taken from Gode et al. (2011), assuming an electricity mix primarily based on nuclear power and hydropower. A factor of 2.1 was used for converting electricity into primary energy, considering a transformation efficiency of 50% and distribution losses in the grid. In the sensitivity analysis, the impact of electricity produced from natural gas was evaluated as an alternative to prevailing production conditions in Sweden.

Different machines and devices are used on golf courses for the many management operations performed. A thorough inventory of all machinery used, its material composition, annual use, life-time etc. was not possible due to lack of site-specific information from the golf courses. Instead, a rough estimate was made by assuming that energy use and GHG emissions from manufacturing, maintenance and repair of machinery comprised 17% of the total energy use and GHG emissions from all turf operations performed. This estimate was based on the distribution between manufacturing and operation phases calculated for Swedish crop production in the same region (Tidåker et al., 2016). The engine oil and hydraulic oil used were assumed to be included in this estimate.

Data on energy use for fertiliser production were taken from Brentrup and Pallière (2008), based on average figures for European production in 2006, while data on GHG emissions were taken from Kool et al. (2012). Data for urea ammonium nitrate were chosen, since the fertiliser products used contained a mixture of urea, ammonium and nitrate. The average diesel requirement for transport of sand was set at 0.4 L km^{-1}, assuming a truck and trailer with empty return transport.

Table 3
Frequency of annual maintenance cycles performed on different parts of the golf courses in Sigtuna and Uppsala.

	Site	Mowing	Aeration	Verticutting	Topdressing
Green	Sigtuna	160	6	14	14
	Uppsala	198	6	8	13
Tee	Sigtuna	88	1	3	3
	Uppsala	82	6	0	1
Fairway	Sigtuna	88	2	0	0
	Uppsala	82	3	0	1

Table 4
Fuel consumption (litres ha^{-1} $occasion^{-1}$) during management operations on different parts of the golf courses in Sigtuna and Uppsala.

		Mowing	Aeration	Verticutting	Topdressing
Green	Sigtuna	3.3	42	11	8.7
	Uppsala	3.6[a]	42	11	8.7
Tee	Sigtuna	8	42	11	8.7
	Uppsala	10.5	21		18
Fairway	Sigtuna	3	9		
	Uppsala	3.2[b]	9		18

[a] On the main course, 188 mowing operations were performed using a pedestrian mower (3.6 L petrol ha^{-1}), and 10 operations were performed using a ride-on mower (7.1 L diesel ha^{-1}).
[b] Mean fuel consumption included the assumption that half the mowing regimes were performed with a groomer with higher diesel use.

Direct emissions of N_2O from soils were estimated using the IPCC default emissions factor (2006), which is 1% of the total N added as mineral fertiliser. In the sensitivity analysis, this emissions factor was applied to the grass clippings.

3. Results

3.1. Energy use per hectare of green, tee, fairway and rough

Energy use was highest for greens, followed by tees and fairways (Table 5). Energy use for green management was roughly three times higher per hectare than for fairways on the same golf course. The lowest energy use was associated with maintenance of rough (7.6 GJ for Sigtuna and 7.1 GJ for Uppsala), which only included mowing and manufacture and maintenance of machinery. Mowing was the single most energy-consuming activity performed for all types of areas. However, the contribution from mowing per hectare was less than half of all energy use (26–45%) associated with maintenance of green, tee and fairway, since irrigation and manufacturing of mineral fertiliser in particular made important contributions. For greens, transport of sand added significantly to the total energy use.

Energy use for maintenance of fairways was considerably higher for Uppsala, which was largely explained by the higher application rate of N fertiliser and sand transport over a longer distance.

3.2. Emissions of GHG per hectare of green, tee, fairway and rough

Emissions of GHG from maintenance of one hectare of green were 6.2 Mg CO_2e for Sigtuna and 6.8 Mg for Uppsala (Fig. 2). Among management activities, mowing contributed most to GHG emissions (23% for Sigtuna and 27% for Uppsala). A major source of GHG emissions was associated with mineral fertiliser (in particular N), both through manufacturing, in which CO_2 and N_2O is released, and through emissions of N_2O from soil after application. In total, mineral fertiliser accounted for 38% of the GHG emissions at Sigtuna and 32% at Uppsala. For Uppsala, the contribution from transport of sand was also considerable.

Emissions of GHG from tees amounted to 4.7 and 6.1 Mg CO_2e ha^{-1} $year^{-1}$ for Sigtuna and Uppsala, respectively. These emissions were dominated by mowing (41 and 39% for Sigtuna and Uppsala, respectively), followed by manufacturing of mineral fertiliser, direct soil emissions (N_2O) and irrigation. Manufacturing of mineral fertiliser and soil emissions of N_2O after application accounted for 41% at both sites.

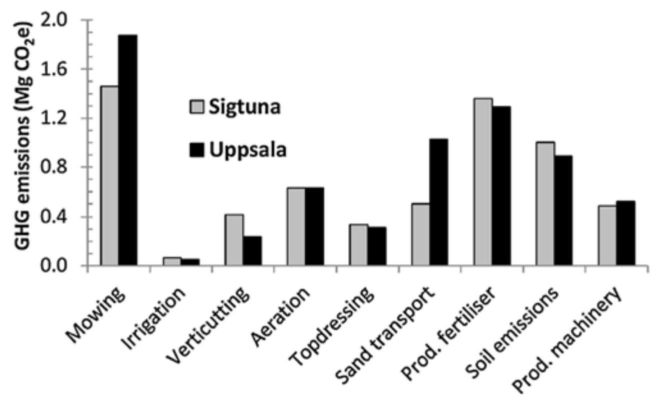

Fig. 2. Emissions of GHG (kg CO_2e ha^{-1} $year^{-1}$) divided into different maintenance activities for greens at the golf courses in Sigtuna and Uppsala.

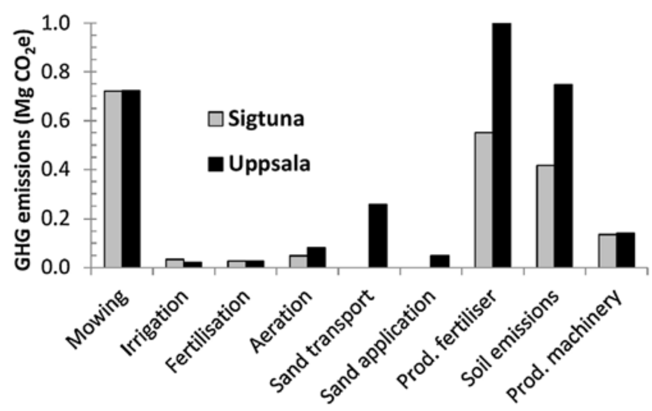

Fig. 3. Emissions of GHG (Mg CO_2e ha^{-1} $year^{-1}$) divided into different maintenance activities for fairways at the golf courses in Sigtuna and Uppsala.

Emissions of GHG associated with maintenance of fairways differed greatly between the sites and were 1.9 Mg CO_2e ha^{-1} $year^{-1}$ for Sigtuna and 3.1 Mg CO_2e ha^{-1} $year^{-1}$ for Uppsala (Fig. 3). A considerable share of the GHG emissions was related to mineral fertiliser, including both the fertiliser manufacturing phase and soil

Table 5
Primary energy use (GJ ha^{-1} $year^{-1}$) split into different maintenance activities for green, tee and fairway at the golf courses in Sigtuna and Uppsala.

	Green		Tee		Fairway	
	Sigtuna	Uppsala	Sigtuna	Uppsala	Sigtuna	Uppsala
Mowing	21	27	27	33	10	10
Irrigation	14	10	14	10	7	5
Verticutting	6	3	1			
Aeration	9	9	1	5	1	1
Topdressing	5	4	1	1		1
Transport of sand	7	15	2	4		4
Fertilisation					0.4	0.4
Mineral fertiliser production	13	13	10	14	5	10
Production of machinery	6	7	5	7	2	2
Total	81	89	61	74	25	33

Table 6
Relative contribution of different maintenance activities to total primary energy use and GHG emissions for the entire golf courses in Sigtuna and Uppsala.

	Energy use (%)		GHG (%)	
	Sigtuna	Uppsala	Sigtuna	Uppsala
Mowing	57	46	54	39
Irrigation	14	10	1	1
Verticutting	1	1	1	1
Aeration	3	4	3	3
Top dressing	1	2	1	1
Transport of sand	2	9	2	7
Production of mineral fertiliser	11	20	16	24
Direct soil emissions			12	17
Production of machinery	11	9	10	7
Total per ha & year	100	100	100	100

emissions of N_2O occurring after application. In total, emissions relating to fertilisation were 50% for Sigtuna and 58% for Uppsala, while the corresponding figures for mowing were 37 and 23%, respectively.

The contribution to GWP per hectare from maintenance of roughs was 0.54 Mg CO_2e for Sigtuna and 0.50 Mg CO_2e for Uppsala. The only aspects accounted for were mowing and production of machinery.

3.3. Energy use and GHG emissions for the entire golf courses

For the golf courses studied, the largest proportion of area was occupied by rough, followed by fairway, green and tee. The results per hectare were therefore converted to values for the entire course in order to obtain information on how total energy use and GHG emissions are distributed between the different playing areas and which activities to prioritise in order to improve the overall environmental performance. In Table 6, energy use and GHG emissions are split into different activities expressed for the entire golf courses, using the areas presented in Table 1.

Mowing was by far the single most energy-consuming activity, and also made a major contribution to GWP (Table 6). Fertilisation affected both energy use and GHG emissions. Emissions of GHG relating to fertilisation (manufacturing and soil emissions) from Uppsala contributed considerably (41%) due to the higher N application rate on fairways and the higher proportion of fairway within the total area. The corresponding value for GHG emissions related to fertilisation at Sigtuna was 28%.

Expressed as area-weighted average per hectare and year for the entire golf courses, the energy use was 14 GJ for Sigtuna and 19 GJ for Uppsala. The corresponding contribution to GWP was 1.0 and 1.6 Mg CO_2e, respectively.

Greens constituted a minor proportion of the golf courses (approximately 3%), but contributed a considerably larger share of the total energy use and GHG emissions (14–17%) due to their intensive management (Fig. 4).

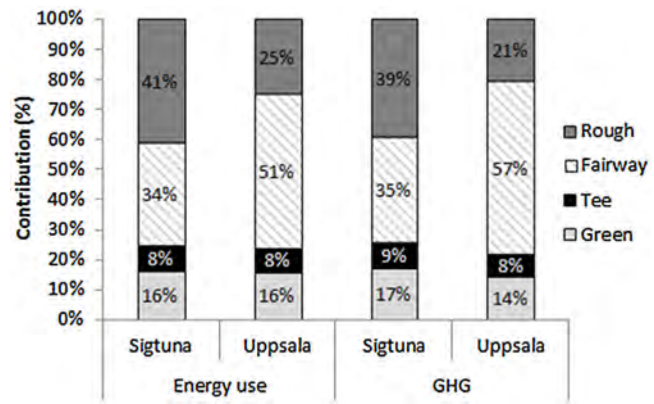

Fig. 4. Relative contribution to primary energy use and GHG emissions split into green, tee, fairway and rough for the golf courses in Sigtuna and Uppsala.

The contribution to energy use and, in particular, to GHG was considerably higher for fairways than its share of the total area within golf courses (19% of the area at Sigtuna and 29% at Uppsala), while the extensively managed rough made a significantly lower contribution than its share of the golf courses (76% of the area at Sigtuna and 66% at Uppsala). For Sigtuna, rough was the area associated with the highest energy use and GHG emissions. For Uppsala, more than half of all energy use and GHG emissions was related to fairway management.

3.4. Sensitivity analysis

Emissions of GHG from electricity production are strongly influenced by its origin. The low carbon footprint from the Swedish electricity mix reflects its large share of hydropower and nuclear power, both associated with low GHG emissions. The assumption in the sensitivity analysis that the electricity used for irrigation was produced on the long-term European margin, i.e. considered to be produced from natural gas, increased the GHG emissions on average by 10% at Sigtuna and 8% at Uppsala. The highest relative increase was obtained for fairways at Sigtuna (Table 7).

Emissions of N_2O were accounted for by assuming that 1% of the N applied as fertiliser was emitted as N_2O—N. However, grass clippings from golf course surfaces are either removed and composted, spread on other surfaces or left on-site. During decomposition of these clippings, N_2O will be emitted. According to model simulations of N_2O emissions from urban lawns, expected N_2O—N losses range between 0.75–3.57 kg ha^{-1} $year^{-1}$ for lawns fertilised with 0–89 kg N, and recycling of lawn clippings has been identified as an important source of N_2O emissions (Gu et al., 2015). The proposed default emissions factor for N_2O—N according to IPCC (2006) for composting in windrows with infrequent turning for mixing and aeration is 1%. This is within the same order of magnitude as

Table 7
Emissions of GHG (Mg CO_2e ha^{-1}) on changing the assumptions as regards electricity mix, N_2O emissions from decomposition of grass clippings and soil carbon sequestration in the sensitivity analysis.

	Green		Fairway		Rough	
	Sigtuna	Uppsala	Sigtuna	Uppsala	Sigtuna	Uppsala
Original setting	6.2	6.8	1.9	3.1	0.5	0.5
Electricity from natural gas	6.9	7.4	2.3	3.4		
Including N_2O from clippings	6.9	7.2	3.5	4.9	1.3	1.4
Including C sequestration			0.8	2.0	−0.6	−0.6

the value reported for garden waste composting in Danish studies (Boldrin et al., 2011). An emissions factor of 1% was used in the sensitivity analysis in the present study, irrespective of how the grass clippings were handled. The N content in clippings, information required for estimating N_2O emissions, was not measured within this study. However, data on net primary production (NPP) of above-ground biomass for the different management areas on the golf courses in Sigtuna and Uppsala were available in another study within the same research programme estimating NPP through frequent sampling during the growing season in 2014 (unpublished data). That study showed that NPP was significantly lower in greens (4.5 and 2.7 Mg dry matter ha^{-1} in Sigtuna and Uppsala, respectively) than in fairways and roughs, but did not differ significantly between fairways and roughs and was on average 11.5 Mg dry matter ha^{-1} in Sigtuna and 12.5 Mg ha^{-1} in Uppsala. Accumulated N uptake in clippings was assumed to correspond to 3% of NPP, which is a rather conservative estimate of the N concentration in frequently cut turfgrass clippings (e.g. Kopp and Guillard, 2002) and is considered the limit for achieving functioning and healthy looking turf in Sweden (Ericsson et al., 2012). In the unfertilised rough, the N concentration in clippings was assumed to be lower (1.5% of NPP) due to less frequent cuttings, as also reported for more mature grass swards in Sweden (Kätterer et al., 1998). As shown in Table 7, inclusion of N_2O from decomposition of clippings had a strong impact on GHG emissions from fairway and rough.

Soil organic C stocks are generally higher in grassland soil than in arable soil (Poeplau and Don, 2013). Since the golf courses studied here were established on arable land, which probably had a history of mixed farming, it is likely that C stocks in the turf have increased since establishment of the golf courses about 50 years ago. The topsoil (0–20 cm depth) in the fairway and rough areas currently contains about 80 Mg C ha^{-1} on average over the two sites (unpublished data), which is 23% more than the C content in mineral agricultural topsoils in the region (Andrén et al., 2008). If this difference in C storage is attributed to turf management over 50 years, soil sequestration in fairway and rough areas would amount to 0.3 Mg C ha^{-1} $year^{-1}$. Thus including soil C sequestration reduced the GHG emissions from fairways considerably and turned roughs into a sink for GHG.

4. Discussion

Energy use and GHG emissions per hectare were considerably higher from greens and tees than from fairways and, in particular, from extensively managed roughs (Table 7). For example, GHG emissions from greens were about two- and three-fold higher than those from fairways at Uppsala and Sigtuna, respectively. Bartlett and James (2011) reported similar differences between greens and fairways in their study on turf management at two British golf courses. Emissions of GHG per hectare from fairways at Sigtuna were of the same magnitude as reported for British parkland courses, while emissions from fairways at Uppsala were about 60% higher. Emissions of GHG per hectare from greens were slightly lower than reported for the British courses, while emissions from roughs were more than two-fold higher in the British study. However, there were some important differences in the maintenance activities performed in the different studies and in the processes included within the system boundary. Dressing, transport of sand and production of machinery were not included in the British study, which explains some of the differences. Moreover, the application rate of N mineral fertiliser and mowing frequency were higher for greens, tees and fairways on the Swedish golf courses included in this study. On the other hand, the GHG emissions from the British parkland rough were significantly higher due to N fertiliser application and high basal respiration (an aspect not included in this study). Emissions of GHG associated with the playing areas (tee, green, fairway and rough) in the study by Bartlett and James (2011), which amounted to 1.7 Mg CO_2e ha^{-1} $year^{-1}$ on average, were similar to those in Uppsala (1.6 Mg CO_2e ha^{-1} $year^{-1}$) but higher than those in Sigtuna (1.0 Mg CO_2e ha^{-1} $year^{-1}$). However, as emphasised above, the GHG emissions were distributed differently among the different playing components, in particular for the roughs.

Mowing made the single highest contribution to energy use for all areas. Introducing electrified machinery for some management operations would be an effective measure for reducing fossil fuel dependency and GHG emissions from golf turf management, provided that electricity is produced with renewable sources and a low carbon footprint.

Another important contributor to both energy use and GHG was mineral fertiliser, in particular N. Most GHG emissions were related to manufacturing of N mineral fertiliser, but N_2O emissions occurring after application also contributed considerably. Since the rather intensively managed fairways constitute a large part of golf courses, the environmental footprint for the entire golf courses was particularly determined by management of the fairways, especially for Uppsala. There was a marked difference in the N rate used on fairways at the two sites. Determining how the N application rate could be reduced on fairways while maintaining turf quality is thus an important step in reducing the environmental burden from golf courses. Assuming that a reduction in N application rate would also reduce turfgrass growth, the need for mowing, and thus the energy use and emissions related to mowing, would decrease.

Irrigation made an almost negligible contribution to GHG emissions due to the low GHG emissions associated with the current Swedish electricity mix. In regions where electricity is produced from natural gas, the contribution from irrigation would increase considerably, as shown in the sensitivity analysis. In regions where electricity is produced from coal, the carbon footprint from electricity would be even higher.

Intensive management, involving irrigation, mowing, fertilisation and recycling of grass clippings, are all activities associated with N_2O emissions (Gu et al., 2015). However, it is unclear how to account for N_2O emissions from grass clippings left for decomposition, since these emissions exhibit high temporal and spatial variability. The assumption in the sensitivity analysis that 1% of the N in grass clippings was emitted as N_2O—N strongly affected the GHG emissions from turf management. Handling of grass clippings is thus a potential hotspot within turfgrass management that needs further examination. Li et al. (2013) observed inconsistent responses when grass clippings were added in turfgrass systems, with soil aeration conditions as one important factor influencing the results. The grass clippings from fairways in Sigtuna and Uppsala were estimated to contain 345 and 375 kg N ha^{-1}, respectively, which made clippings an important source of N in the turfgrass system. Gu et al. (2015) advocate recycling of grass clippings as a means of lowering the N application rate. Exploiting the fertiliser value of recycled clippings in different conditions and reducing the application rates of mineral N fertilisation could be an effective management option for reducing N_2O fluxes from golf courses.

Soil C sequestration is an important measure to offset GHG emissions from turf management. An assumed soil C sequestration rate of 0.3 Mg ha^{-1} $year^{-1}$ for fairways and roughs in the present study resulted in a considerably lower carbon footprint for the Uppsala course (0.5 Mg CO_2e), while the GHG emissions from Sigtuna were totally eliminated. In a recent Swedish study, frequently cut urban lawns were found to contain 55% more soil C than surrounding arable soils (Poeplau et al., 2016). Perennial plants such as turfgrass generally have denser root systems than annual crops (Wang et al., 2014) and root-derived C is preferentially stabilised in soil (Kätterer et al., 2011). This is the main reason why an increased frequency of perennial forages in crop rotations (Bolinder et al., 2010) or a land use change from arable to permanent grassland leads to soil C sequestration (Kätterer et al., 2008). High C sequestration rates following conversion of farmland to golf courses have been reported in several studies. For example, Selhorst and Lal (2011) reported sequestration rates as high as 0.44 Mg C (corresponding to 1.6 Mg CO_2e) ha^{-1} $year^{-1}$ on average over a period of 91 years in fairway and rough areas on farmland converted to golf courses in Ohio. Even higher sequestration rates (0.9 and 1.0 Mg C ha^{-1} $year^{-1}$) were reported by Qian and Follett (2002) for fairways and greens on 16 golf courses in the USA. However, their study was more short-term (25–30 years) and this sequestration rate will probably not persist in a longer time perspective, since soil C sequestration rates are known to decrease with time until a new steady state soil C content is reached (Andrén and Kätterer, 2001). Compared with those values, the estimated sequestration rate for fairway and rough of 0.3 Mg C ha^{-1} $year^{-1}$ for our two Swedish sites was fairly low, although only slightly lower than the median C sequestration (0.42 Mg ha^{-1} $year^{-1}$) recorded in ley-arable rotations in 15 long-term field experiments under Nordic conditions (Kätterer et al., 2013). While the uncertainty in our estimates is high, since we had to rely on several assumptions due to lack of data, the higher sequestration rates for similar systems reported in the studies cited above suggest that our estimated sequestration rate of 0.3 Mg C ha^{-1} $year^{-1}$ is rather conservative and its inclusion in this LCA would not have overvalued the importance of soil C sequestration.

5. Conclusions

Energy use and GHG emissions per unit area were highest for greens, followed by tees, fairways and roughs. However, when considering the entire golf courses, both energy use and GHG emissions were mainly related to fairway and rough maintenance due to the larger area they occupied. Mowing was the most energy-consuming activity and contributed 21 and 27% of the primary energy use of the golf courses. Irrigation and manufacturing of mineral fertiliser and machinery also resulted in considerable energy use. Mowing and emissions associated with fertilisation (manufacture of N fertiliser and soil emissions of N_2O occurring after application) contributed most to GHG emissions. Emissions of N_2O from decomposition of grass clippings are a potential hotspot for GHG emissions from turf management that needs further investigation, since the high spatial and temporal variability of these emissions makes it difficult to estimate their actual contribution. Including the estimated mean annual soil C sequestration rate for fairway and rough in the assessment considerably reduced the carbon footprint for fairway and turned the rough into a sink for GHG. Appropriate measures for reducing energy use and carbon footprint from lawn management are thus: i) reduced mowing frequency when applicable, ii) investment in electrified machinery, iii) lowering the mineral N fertiliser rate (especially on fairways) and iv) reducing the amount and transport of sand for dressing. Lowering the mineral fertiliser rate is of particular importance, since GHG emissions originate from both the manufacturing phase and from N turnover after application. However, measures must be adapted to the prevailing conditions at the specific golf course and the requirements set by golfers. There is also a need for more golf courses that prioritise and market a low environmental footprint even at the expense of e.g. current aesthetic preferences. A life cycle perspective as applied in this study can be used as a tool for decision-support for golf courses aiming at improving their environmental performance.

Conflict of interest

We declare that no conflicts of interest of any kind (direct or indirect) exist.

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ARTIKEL NR 6

Golf courses as a part of urban green infrastructure: social aspects of golf courses and extensively managed turfgrass areas from Nordic perspective

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1. Introduction

Originating in Scotland in the 15th century, the game of golf became very popular first in Europe, later in all English colonies and finally, by the end of the 20th century, around the world. With urbanisation in new urban districts, quite large open areas are designated for golf courses and are considered to be an important part of urban green infrastructure (Zhang 2014). However, the high level of resource input and intensive maintenance and management practice of golf courses is criticised by some ecologists and environmentalists. A paradigm shift is now required towards creating multi-functional sustainable public spaces.

In the Nordic countries managed turf-grass areas and golf facilities have been increasing since the second part of the 20th century. The Nordic golf federations have more than 900,000 members, playing golf on 1071 courses that cover a total area of more than 65,000 ha (Golf around the World 2015). The popularity of golf is partly connected to the growing market economy, increasing incomes and economic stability. There are probably many other factors connected to the modern Western lifestyle, which might explain the popularity of golf (such as health aspects, experience of nature, and social interaction, etc.). Swedish golf courses are seen by many golfers as an arena for meeting, socializing and enjoying nature. Many golf courses are located in or near attractive nature and landscapes such as lakes and forest margins.

We researched golf courses within the interdisciplinary project "Lawn as a cultural and ecological phenomenon" run by scientists from SLU, Sweden and funded by the Swedish Research Council (FORMAS). One of the goals of this project was to study the range of different managed lawns from the most intensively managed urban conventional lawns to the more meadow-like lawns. The parterre lawn, requires the highest management intensity, but parterre lawns are uncommon in Sweden. Instead golf courses were included in our project. Golf courses have a wide range of lawn types and playing surfaces, from very intensively managed greens and tees to fairways with intermediate management practices and roughs with the lowest management intensity. Golf courses in this sense can be seen as a microcosm where all types of planted grass communities (lawns) are presented (fairway, rough and high rough).

During the last decade in Sweden there has been a driving force to develop greater numbers of multifunctional golf courses, which can provide a whole range of ecosystem services such as improving biodiversity (creating habitats for grassland and wetlands), and providing recreational areas, which are accessible for the public. STERF (Scandinavian Turfgrass and Enviromental Research Foundation) is one of the main promoters of this movement (Strandberg et al., 2011). An important peculiarity of Swedish golf courses is the use of only small or very small amounts of fungicides, herbicides and fertilizers.

This particular research related to golf courses was supported by STERF.

2. Methodology

Our data collection methods in this research are surveys, interviews, observational studies and document studies. Six golf clubs (GC) were selected in three geographic regions of

Sweden (Gothenburg, Malmo / Lund and Uppsala / Sigtuna): Sigtuna GC, Uppsala GC, Malmö Burlöv GC, Lund University GC, GC Delsjön and Torslanda GC.

A total of 180 golfers and 12 golf course employees are included in the study. Observational studies in the golf environment were aimed at getting an idea of where the visitors went to when they were not playing golf. We have also studied the selected golf clubs' websites and published writings.

3. Results and discussion

The social part of this study has been focused on the golfers' and the golf course managers' perspectives. The main research question was "What is appreciated by golfers in their golf course when it comes to green environment and ecological, cultural and social values?" The interviews indicated that the time spent on the golf course includes much more than just the game itself. For many players visits to the golf course also act as an experience of nature and the beautiful surroundings, as a social context (interaction), a way to stay in shape (fitness), as well as a way to relax (recreation).

The Golf course as a social arena

Golfers indicated that in golf clubs they are able to meet friends and make new social contacts in golf clubs. Players stressed that here they feel included in a social context where all share the same interest - the game of golf. The restaurant as well as shops and other activity arenas on the golf course are important social meeting points. Many golfers also use other golf courses within and outside Sweden. Partly they do this in order to try other golf courses (challenges) and to extend the playing season (which is short in Sweden) by traveling to warmer countries. One of the players said: "*Golf is an important part of my life. This is where I and my wife (sic) meet after work. Here we meet our friends. Here we spend a lot of time, sometimes even the whole day. Then there must be more than just good courses. Periodically, the golf club is our second home during the summer season*".

The Golf course as an experience arena (perception)

Natural values often mentioned by the golf players were: quiet, peaceful environment (silence), sound (hearing of birds), seeing butterflies and small animals as well as the presence of plants. The existence of the "natural environment" is perceived as a very important feature for choosing a specific golf club. For example, one of the golfers said: "*It is so beautiful to have birch trees and flowering meadow as a background for this golf course*". Another player said: "*When I finish playing in this well-kept environment of golf, I want to enjoy being in the surrounding nature. I am so happy to do a little walk in the beautiful surroundings. I have my favorite place where I meet my friend – a hare. The place also has a rich birdlife which I do not notice (sic) as much when playing on the golf* fairways".

Golfers also enjoy the pleasant smells and sounds of nature as well as the presence of water (lake, pond and river).

Vision of biodiversity

The environmental aspect seems to be important for many of golfers. The majority of respondent players said that the golf course was a great environment for biodiversity for animals and plants. For example, 114 from the 180 interviewees said that the golf course was a good environment for biodiversity. Some of the players were skeptical. One of them said: "*No, voles and hares and things like that should not be here. They should stay away from the golf course. The grass must be free from weeds. Greens must be well maintained. I have my garden at home.*"

The Golf course as an activity sport´s arena

For golfers generally, the game itself, of course, is the primary reason for being at a particular golf course. However, many players noticed that the game is combined with other added values. Many of those interviewed described their vision of a "good" and well-functioning golf course as:

-the golfing environment should be maintained in an environmentally friendly manner

-the golf holes in various parts should be of high quality

-the golf course should be located in a beautiful and quiet environment

-the golf course design should be of good quality in terms of management and playability

-the golf course must be neither too demanding nor too easy.

-the golf course should have necessary features/services that golfers need during a day's stay.

Golfers appreciate some additional features such as good communications, easy access and closeness to home. Many of the golfers also mentioned the importance of cultural aspects.

Lawns and their significance for golfers

A golf course consists of four main parts: tee, fairway, rough and green. The tee is a smooth flat lawn area which is always cut very short. The fairway is an intensively short-cut, elongated lawn area in the direction towards the green that is surrounded by a rough area that consists of higher grass that is cut less frequently. A green is a high-intensity trimmed lawn which is mown daily during peak season. Tees and fairways are not cut as frequently (approximately 3 times per week). The rough is the part of the golf course that is least maintained and cut about once per week or less (interviews with green keepers and managers on golf courses in the Swedish Lawn project, February 2015).

Many of the interviewees valued not only the game, but also the green (both in terms of the quality of playing surface, which sometimes even becomes tanned by the sun or because of the intensive maintenance) but also the 'natural' green areas found in the local environment. In other words, "wild" nature embedding the golf course, is often seen as a valuable additional complement to the professionally designed and well-kept playing surfaces of the golf course.

The manager's vision of golf courses

Interviews with employees were conducted in all six golf courses. All golf course managers have high ambitions when it comes to offering a good quality golf course. The main challenge for all golf courses was to find the balance: how to offer good playing surfaces and well-maintained and attractive golf courses in tight economic conditions. Several golf clubs mentioned the problem of competition between different clubs. Membership fees are not always sufficient for the high ambitions that the clubs want to offer when it comes to course quality and service. The common feature in all studied cases was increasing demands from players in terms of quality of the golf holes (tidy and smooth to play on) and at the same time requirements from municipalities and county councils to address the environmental issues. One of the interviewees said: "*Our players want the best possible quality of the golf course for minimal expenses. A sound principle we try to live up to. Without bragging, I think we can handle it quite well.*"

Two of the golf courses that are included in our study are nature conservation areas. Here the use of pesticides is completely prohibited. It is known that sometimes turf grass suffers from diseases caused by fungus and in this case pesticides are usually used. But in the case of golf courses in nature conservation areas it can be used only occasionally and under strict control. Irrigation and fertilization are also controlled in these areas. Delsjön GC is one of those golf clubs that has been given permission to build a pond to meet irrigation needs. In the second case, Lund University GC, a certain quantity of water is taken from the nearby lake for irrigation purposes. In both cases the golf courses must apply for permission for all major construction jobs, the supply of soil, and tree cutting. The golf courses' business in nature conservation areas is very much driven and controlled by the authorities. One of the employees said; "*In this way we have been forced to become an eco-friendly golf club. Sometimes such policy pays off in the end and our players really appreciate this nature conservation component. We see this as a competitive advantage and believe in this positive trend where more and more of the maintenance of managed turf grass areas and golf courses are controlled by environmental goals*".

We can also conclude that golf course managers expressed high ambitions when it came to environmental issues. This applies to mowing, watering, and use of pesticides and fertilizers on golf courses. For example, one interviewee said: "*We investigate the situation carefully before we invest in any machines or change our maintenance routines. The aim is to meet the environmental requirements. But this is sometimes difficult to do. Today there* *are, for example, good electric mowers but they devour batteries at a furious pace, and these batteries are very expensive. So it will not be as environmentally friendly in all cases in the end. The hybrid machines available today are certainly good but too expensive so far. So we compromise as much as possible to balance both environmental requirements and our economic reality* ".

One course manager said: "*Previously, we had a strict schedule for the days we would irrigate and run different kinds of management, how often, etc. Now we have introduced the principle – "if and when it is necessary" - which gives both economic and environmental savings. It's about common sense instead of overly strict procedures*".

All golf course managers have a desire for creating a "*beautiful green natural environment*" with flowering plants, shrubs, trees and ideally, with water presence. For example, one of the course managers said: "*It would be fun to make the environment a bit more inviting by planting more plants. But we cannot do anything without permission from the County Administrative Board. Plants that do not belong to the natural and original environment are not allowed here since this area is classified as a nature conservation area. But we have many other values for example a beautiful meadow which reaches its peak around midsummer.*"

When it comes to grass quality the wish list of course managers and green keepers is:

- A long summer season with just enough rain and sun.
- Sustainable and easy maintained grass species and varieties that are tolerant to diseases and can compete with weeds.
- Playing surfaces without diseases caused by fungus and weeds.

When we asked about a "good" golf course design, both players and managers had quite similar answers:

- The golf holes provide good playing quality and are framed by 'natural' scenery with shrubs, trees and, in an ideal case, with some waterbodies.
- The course should be a bit hilly (not only flat).
- Birdlife is also a desirable element in the environment.
- Fairways should provide enough challenging and exciting experiences while walking during the game.

It also appeared that there is sometimes a conflict between green keepers and players' expectations of a golf course. "*Here we have players who enjoy the sweet and cute bunnies moving in our course. We as green keepers see them as pests because rabbits definitely will give us troubles. Some players complain if they see a snake. And I am often happy if snakes are here because they help us to keep away mice and voles.*"

4. Conclusion

Our results show that the golf course environment is often seen as a multidimensional, valuable environment. Most of the interviewees were not only dedicated golfers who enjoy the game itself. They combine golf exercise with a lot of other values. That is why golf courses have great potential to support multiple values: for example, biodiversity and carbon sequestration as well as social wellbeing of people. The green environment of golf courses is often seen as a part of nature and the visit to the golf course as an outdoor activity in nature.

Perception and cognitive processes are an important part of the total experience for golfers. Green spaces and places in golf courses are giving signals of different kinds to the senses. Our impressions from what we are seeing, hearing and smelling impact upon our feelings of well being (Gehl, 2001). Outdoor acitivities in public places and spaces, like possibilities for pleasant walks and access to places for standing, sitting, meeting, talking and to find a convenient place for relaxation and pleasure after the game, are important according to the golfers we interviewed. Golf courses include large areas of land that are not used for the game of golf. Therefore, there could be potential for better use of the land in many cases in order to provide new opportunities to create an active outdoor life for other groups in addition to golfers. Some of the managers and green keepers mentioned the possibility of opening and inviting others to the golf courses (not only golfers). In this way golf courses can be valuable green areas for recreation in close proximity to urban areas.

Further work will focus on environmentally-friendly design and management on golf courses that can be part of the bigger urban-green infrastructure picture. This could be an important strategical tool for the future of golf. Golf courses could also have the potential to contribute to supporting wild flora and fauna, particularly in urban and peri-urban settings where they could contribute significantly, for example, to wetland creation (Strandberg 2012; Strandberg 2014) and in preserving "a functioning biotope or ecosystem" which "is of crucial importance in preserving the original vegetation" (Florgård, 2009: p 380).

Fig. 1. A golf player practicing putting March 2015 at Burlöv golf course (in Malmö, Sweden).

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Inledningsvis presenterar vi resultaten från forskningsprojektet och diskuterar befintliga alternativ till konventionella gräsmattor från Europa och Nordamerika. Sedan analyserar och diskuterar vi erfarenheter från Sverige, inklusive våra egna försök på Campus Ultuna vid SLU i Uppsala. Vi bidrar också med praktiska råd om hur man kan etablera och förvalta olika slags alternativ till gräsmatta som är lämpliga för svenska förhållanden.

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