



Intensive Mapping of Golf Courses: Application for Site Specific Management

高爾夫球場密集空間投影：
對特定場地管理之應用

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**Please note that Chinese subtitles are for
reference only.**

請注意：中文翻譯謹作參考用

Outline大綱

- Introduction to Precision Turf Management
精密草坪管理簡介
- Site-Specific Irrigation
特定場地之灌溉
- Site-Specific Fertilization
特定場地之施肥
- Site-Specific Cultivation
特定場地之耕耘
- Conclusions
結論

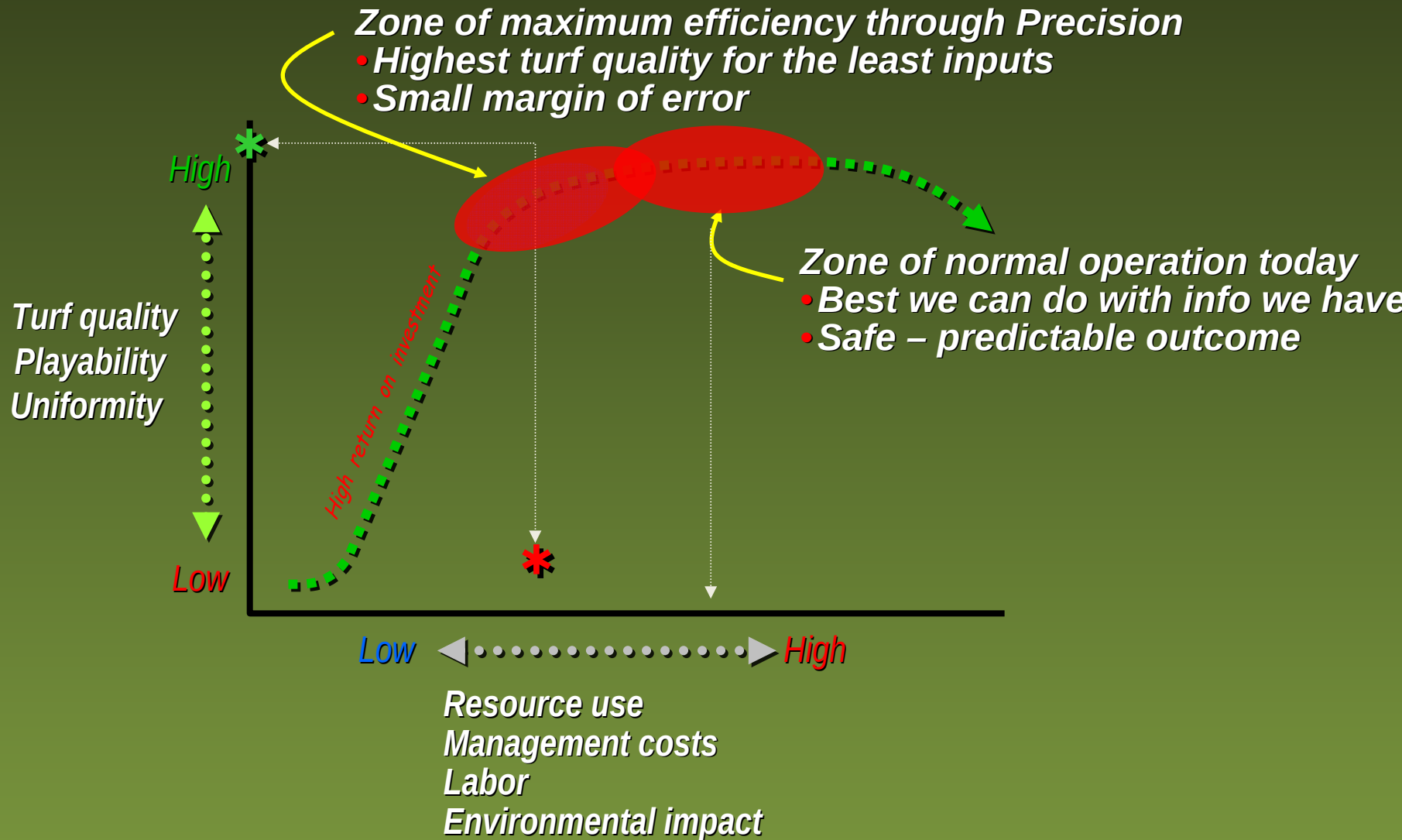


Precision Turf Management:

精密草坪管理

Turf Quality vs. Inputs

草的品質 vs. 投入



Basic Premise of PTM

精密草坪管理基本前提

- The basic premise of PTM is **site-specific management**
精密草坪管理基本前提是特定場地的管理
- Applying inputs (water, fertilizer, etc.) **only** where needed, when needed, and in the amount needed
只在需要的地方,需要的時候及所需要的數量時投入資源(水,肥料等)
- Fosters more **precise** and **efficient** application of inputs
鼓勵更精確及高效率的資源運用

Basic Premise of PTM

精密草坪管理基本前提

- Management at a **smaller scale** than current practices

管理方法比當前的做法規模較小些

- Can be applied to golf courses, athletic fields, and sod farms

可以應用於高爾夫球場、運動場、和草皮生產場

Precision Turfgrass Management

精密草坪管理

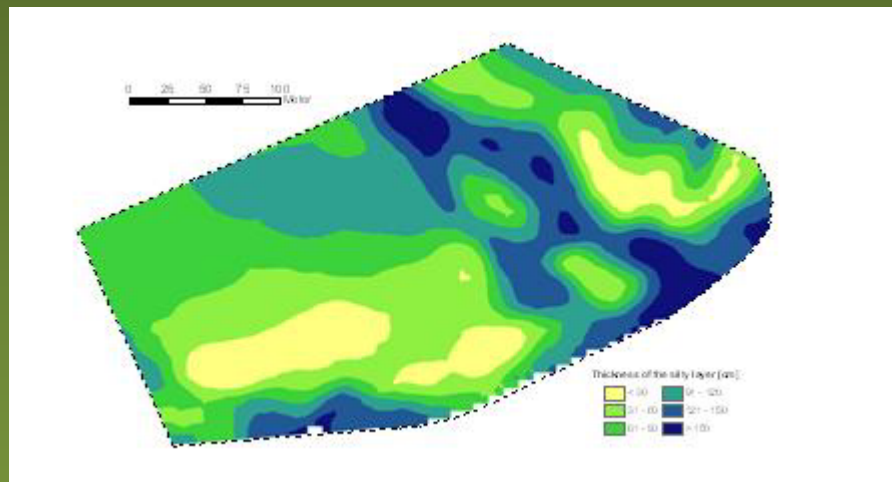
- Requires intensive site assessment
需要密集的場地評估
- Necessary tools: 所需的工具/機械
 - **Sensor technology** in mobile platforms capable of spatial mapping on a high density grid
 - **GPS** (global positioning systems)
 - **GIS** (geographic information systems)
 - Produce maps 制成圖表

Spatial Variability

空間的變異性

- A primary reason for spatial mapping of soil and plant parameters is to determine spatial patterns and variability, especially of soil compaction and water
- 進行空間投影的主要原因是確定區域內土壤和植物的模式和變化,尤其是土壤的和板結和水份

土壤和植物的變數於空間映射的主要原因是確定空間格局和可變性，尤其是對土壤板結和水



Toro Precision Sense 6000™

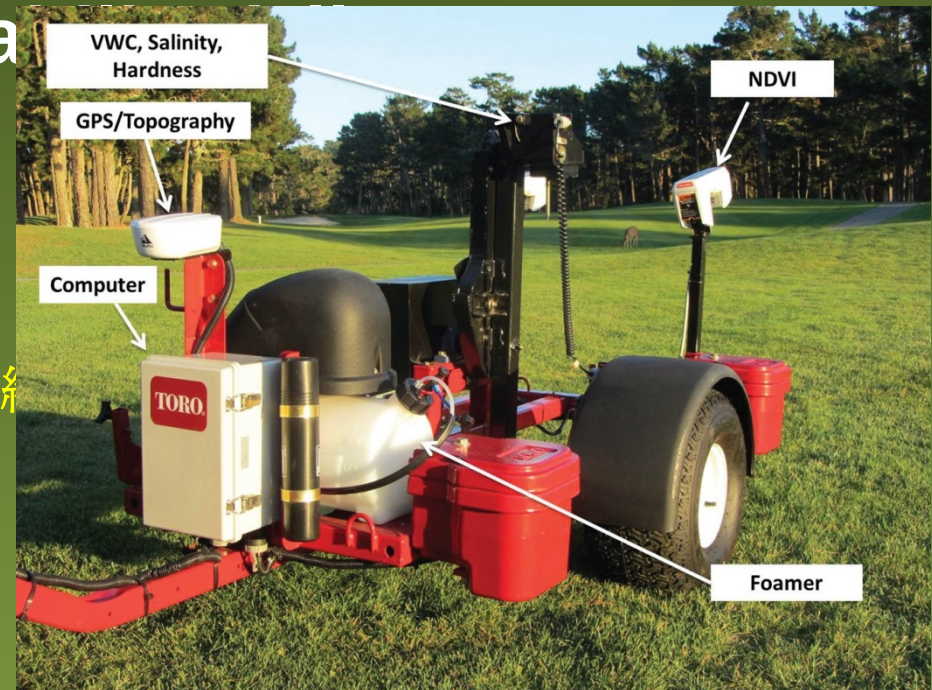
- Data acquisition unit – produces detailed maps
 - 1 ½ hours to map one whole golf hole

資料採集機械 - 可在1個半小時完成一個高爾夫洞詳細的投射地圖

- Multiple-sensor capability (referenced)

具多種感測性能

- Soil moisture 泥土濕度
- Soil compaction 泥土板結
- Soil salinity 泥土含鹽量
- Plant health/vigor 植物健康/活性
- Elevation 海拔(高度)



Toro Precision Sense 6000™

- % VWC
- Penetration resistance

貫穿抗力



ity

Toro Precision Sense 6000™



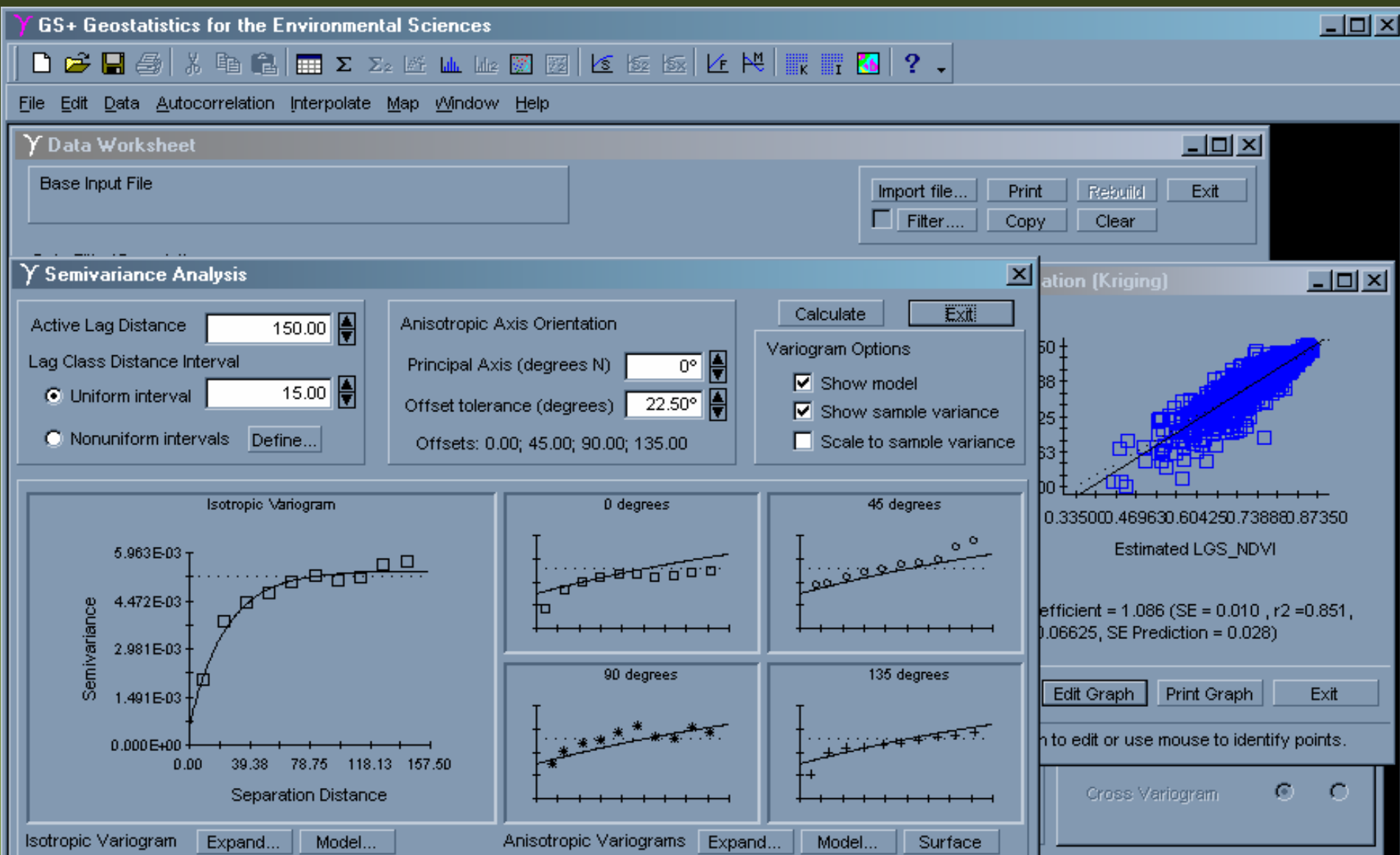
- Elevation
- Geo-referencing



- Plant performance –
NDVI



ArcView data analysis & interpolation by kriging – a method of interpolation which predicts unknown values from data observed at known locations using distance-weighted averaging



GIS (computing power...)

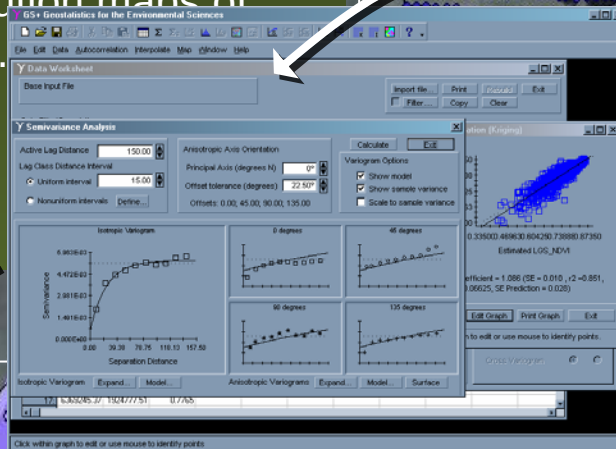
Geographical Information System

Data Interpolation

Sampled data is Interpolated using “kriging” to create spatial distribution maps of site attributes.

- Sample data ~1 pt./100 ft²
- 435 pts./ac. or ~1000 pts./frwy

Sampled data points for VWC
8' x 8-16" grid



- Sample data interpolated to a 2' x 2' grid
- Interpolated data 1 pt./4 ft²
- Or ~25,000 pts./frwy

PrecisionTM Sense process: data collection, analysis & implementation

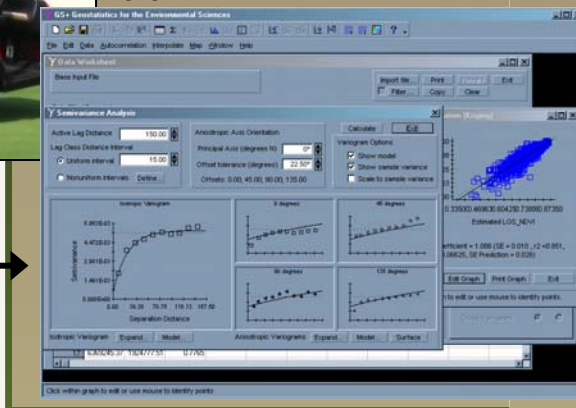
1 Data collection
On-site – Distributor



← **On-site** **At Toro** →

2

GIS ArcView processing & analysis
Toro



Data transmitted electronically to Toro

3 Primary Data Products (Google Earth format)
Toro



Soil moisture

Soil salinity

Turf vigor

Topography

Soil compaction

Field Implementation

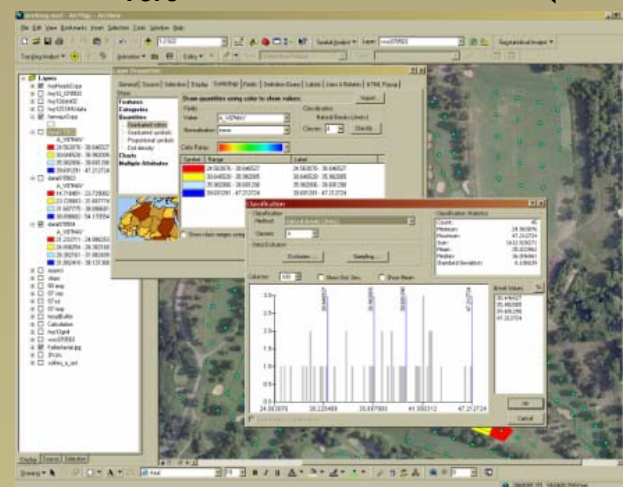
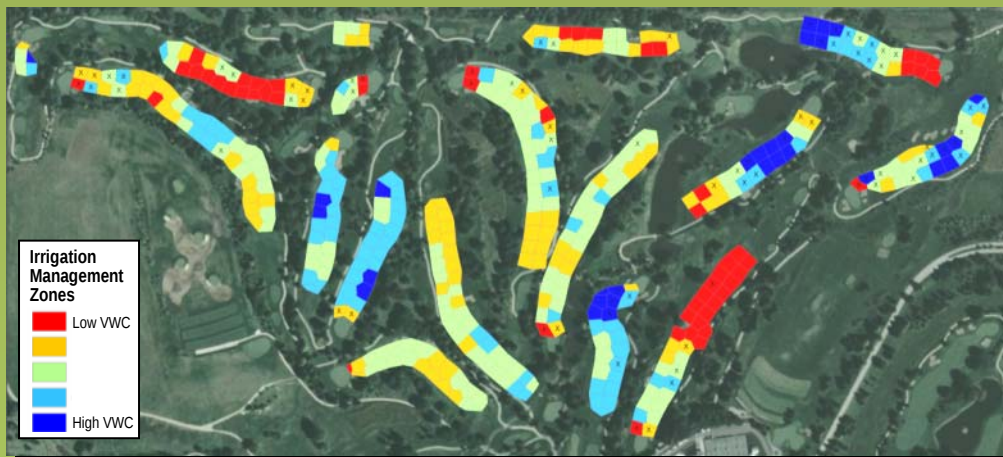
On-site – Distributor consultant

5

- Irrigation corrections made from audit
- Irrigation management zones defined
- Turf Guard sensors located & installed
- SitePro/Lynx customization
- Etc.

Analysis products delivered back to customer electronically

4 GIS application analysis & products, Interpretation & recommendations
Toro



Site-Specific Irrigation

特定區域之灌溉





Irrigation Efficiency

灌溉(澆水)效率

- **Background: 背景**
 - **Golf courses often require excessive amounts of irrigation water to maintain adequate turfgrass playability and aesthetic quality, because most irrigation systems are outdated, improperly installed, and/or infrequently checked for water application uniformity**

高爾夫球場往往需要過量的灌溉水，以維持足夠的草坪草可玩性和美觀，因為大多數灌溉系統已過時，安裝不正確，和/或不經常檢查澆水量的均勻性。



Irrigation Efficiency

灌溉(澆水)效率

- Requires timely and accurate site-specific information

需要及時和準確的特定區域的資訊

- Involves the application of water where needed, when needed, and at the amount needed

涉及到水的應用，於需要的地方，在需要的時候及需要的數量

- Results in irrigation management at a smaller scale (down to a single irrigation head or less)

使用較小規模灌溉系統的結果 (到單個灌溉頭或更少)

- Dependent on detailed site-specific information obtained through intensive site assessment to account for spatial variability

依賴密集地區評估取得該區詳細的資訊，說明空間的變異性

Current Approach - Catch Can Method



現時採用的方法 是杯計

- Assessment usually based on a small number of samples

評估通常基於較少數目的樣本

- Measures distribution uniformity

可量度分佈的均勻性

- No indication of “effective” irrigation

不能表明“有效的”灌溉

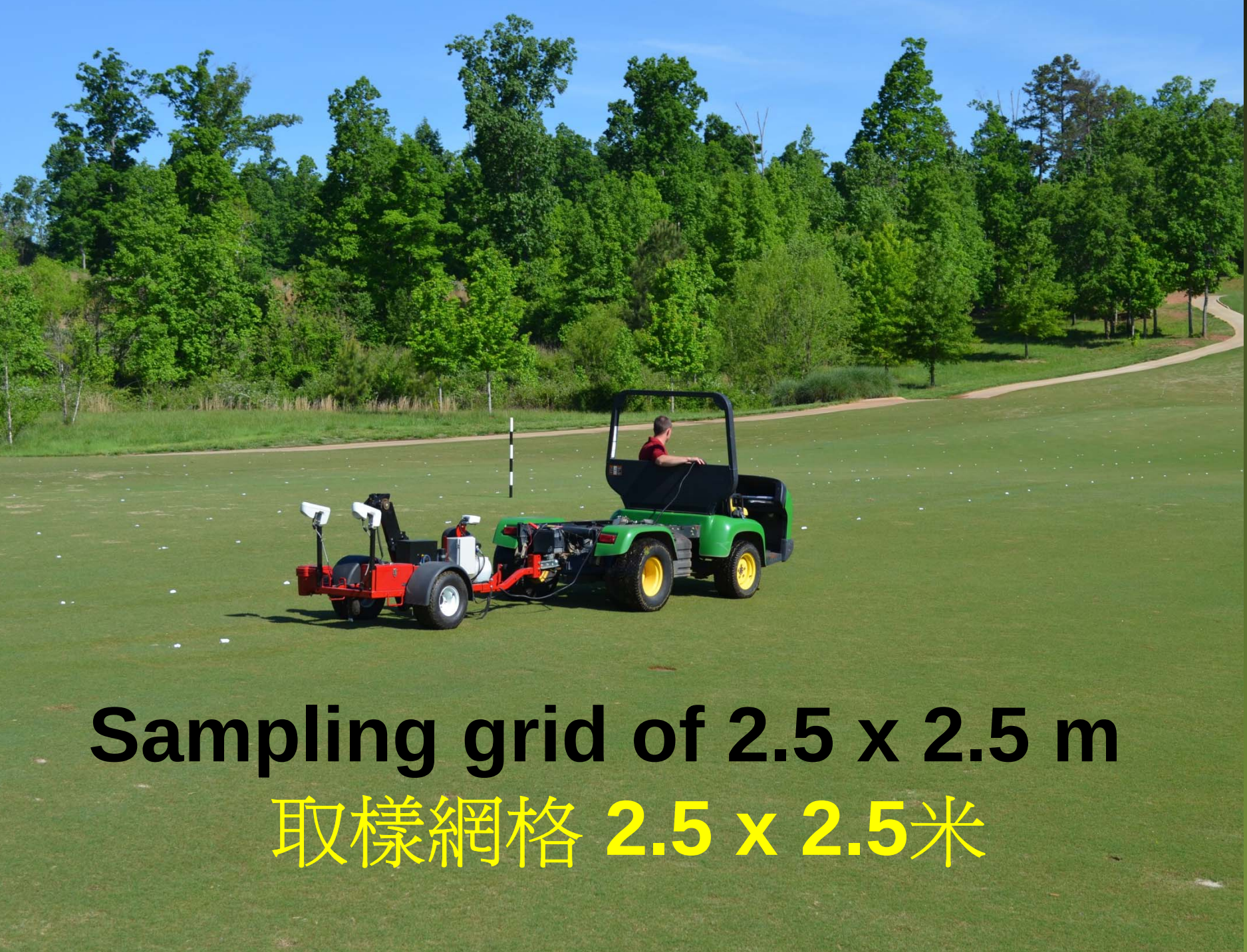




New Water Audit Approach

新的澆水審計辦法

- **Two Phases:** 分兩步驟
 - **Assessing the system for optimum performance**
評估系統以達最佳性能
 - **Assessing for spatial variability of system water application or soil distribution**
評估噴灌系統之應用或土壤分佈的空間變異性
 - **Soil moisture assessment under drier conditions. Mapping wall to wall.**
在乾燥程況下作出土壤濕度評估。由一方至另一方。
 - **Includes:** 包括
 - **Whole system assessment** 全個系統
 - **Head by head assessment** 由一噴頭至另一噴頭



Sampling grid of 2.5 x 2.5 m

取樣網格 2.5 x 2.5米

New Water Audit Approach

新的澆水審計辦法
Soil Moisture - % VWC



Head-by-Head Evaluation

噴頭至噴頭的評估

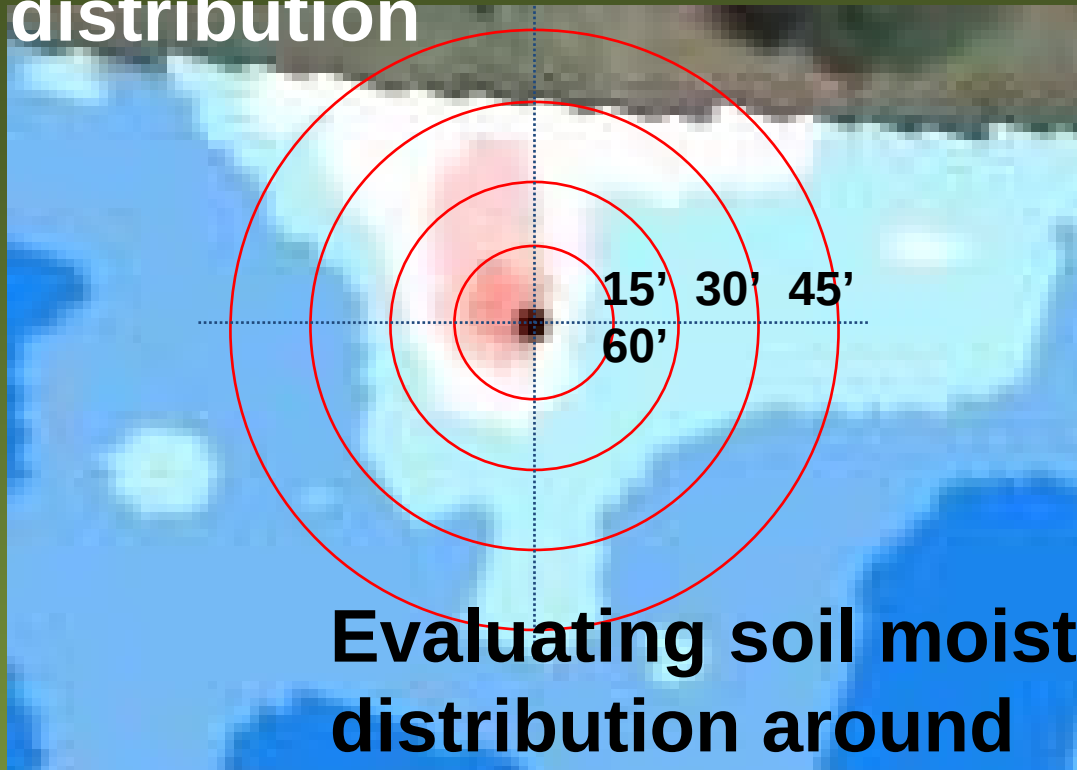




Red flag limits can be set for VWC parameters that would ID heads not operating within prescribed limits. Each quadrant can be evaluated to determine direction of water distribution

New Irrigation Audit

新的灌溉審計



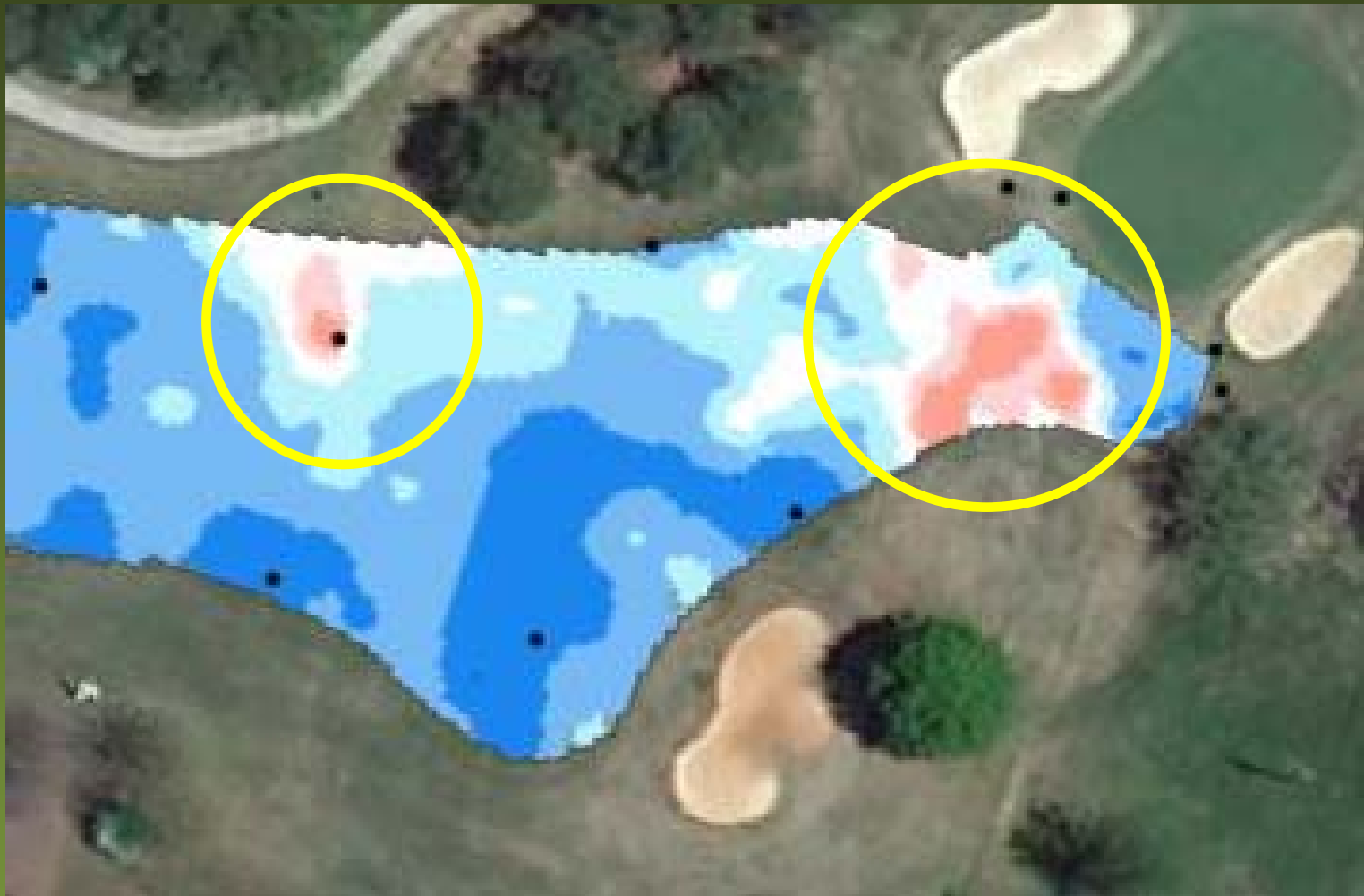
Evaluating soil moisture
distribution around
individual sprinkler heads

Mean VWC		
0-15	15-30	30-45
45-60		
42.4	31.5	17.3
19.9		



New Water Audit Approach

新的澆水審計辦法



ID of Easily Correctable Problems



鑑定易於改正的問題

When a problem head is identified, field investigation is conducted to determine:

當一個問題噴頭確認時，進行現場調查，以確定

- **Incorrect scheduling** 錯誤的安排
- **Localized dry spot** 局限性的乾點
- **Head alignment** 噴頭的調整
- **Head not operating** 噴頭失效
- **Head spacing** 噴頭間距
- **Wrong nozzle size** 錯誤噴嘴
- **Sprinkler or nozzle wear** 噴頭和噴嘴損耗
- **Mismatched sprinklers or nozzles** 噴頭和噴嘴不配合

A photograph of four golf course maintenance workers in red shirts and khaki pants. One worker in the foreground is pushing a green JESCO fertilizer spreader, which is dispensing a fine mist of fertilizer onto the grass. Other workers are visible in the background, some standing and others near a red utility vehicle. The scene is set on a lush green golf course under bright sunlight.

Site-Specific Fertilization

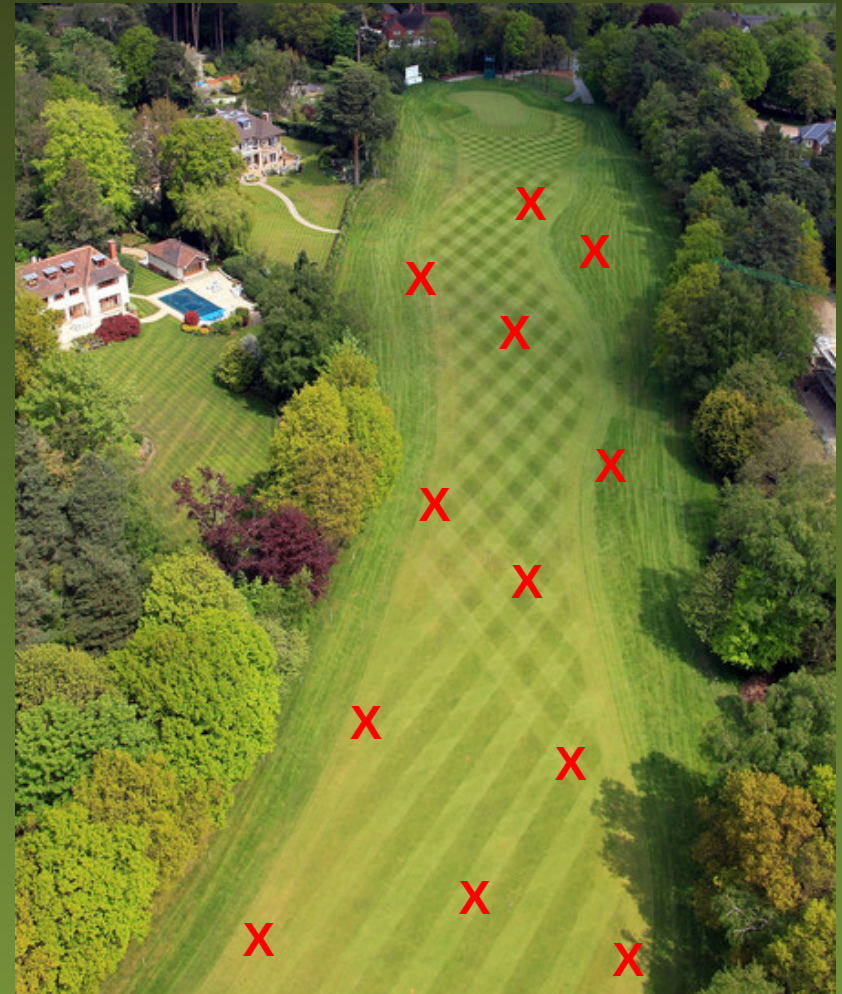
特定地區的施肥

Current Sampling Practices



目前的取樣方法

- Random soil sampling
隨意泥土取樣
- 10 to 20 soil samples taken over a given area
在指定地方收集10-20樣本
- Does not take into consideration soil texture spatial variability
並無考慮泥土質地的空間變異性



Current Sampling Practices



目前的取樣方法

- A composite sample is created

製造一個複合的樣本

- A sub-sample is analyzed for texture and nutrient content

抽樣分析質地和養分含量

- Fertility recommendations are made based on the composite sample

土壤肥力的建議基於複合樣本



Site-Specific Fertilization



特定地區的施肥

- Golf course holes are mapped with the Toro Precision Sense 6000 when the soil is at field capacity

當土壤是在濕度臨界點時可在高爾夫球場使用**Toro Sense 6000**機作投映

- Field capacity is the water holding capacity in the field after water drainage due to gravity
 - 濕度臨界點是土壤在因地心引力作用排水後的保水能力
 - Soil moisture maps in conjunction with NDVI maps are used to create soil texture maps
- 土壤濕度圖與 **NDVI** 地圖結合可用於建立土壤質地圖

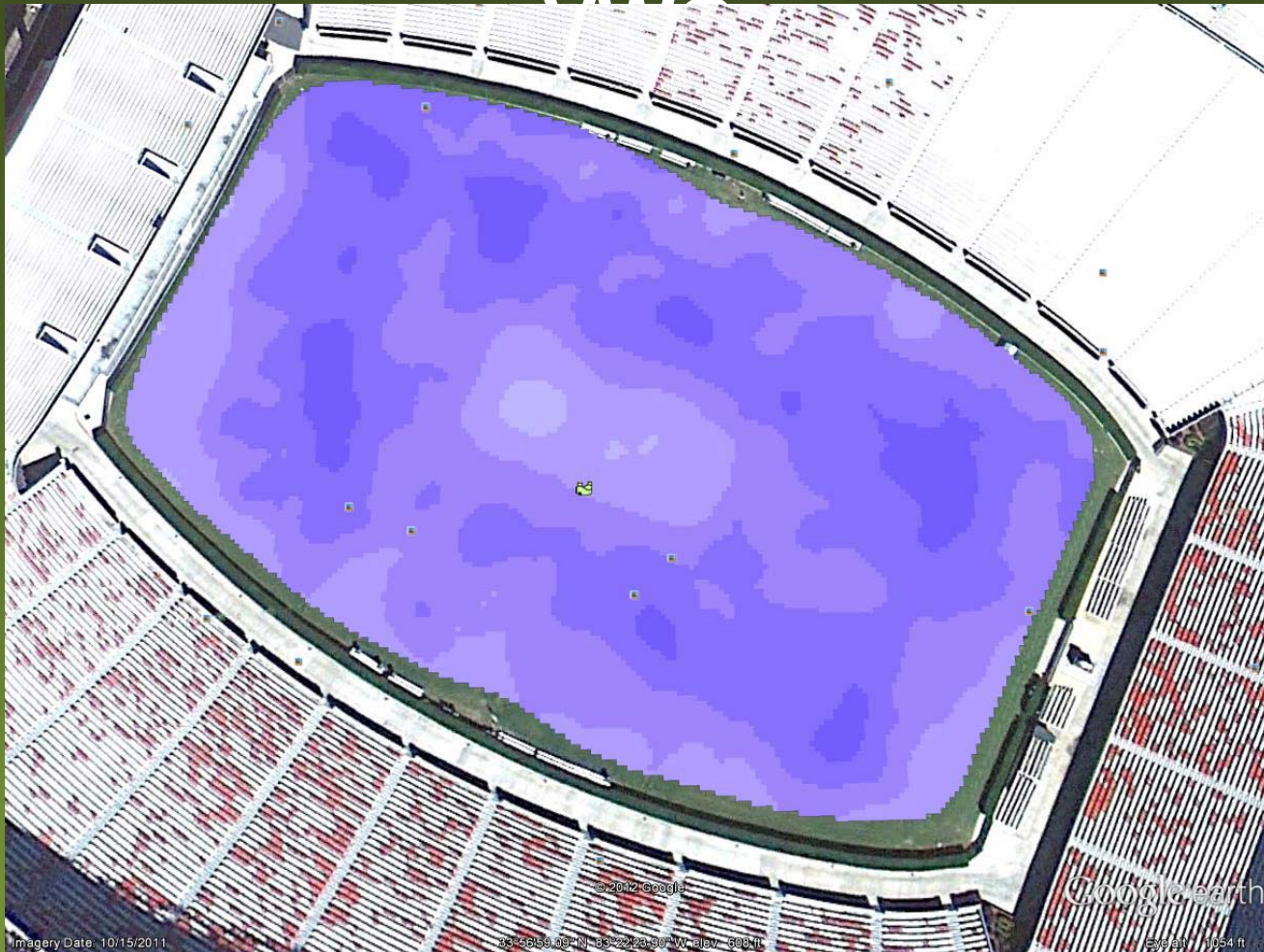


Sampling grid of 2.5 x 2.5 m

取樣網格 2.5 x 2.5米

Site-Specific Fertilization

特定地區的施肥
Soil Moisture 土壤濕度- %



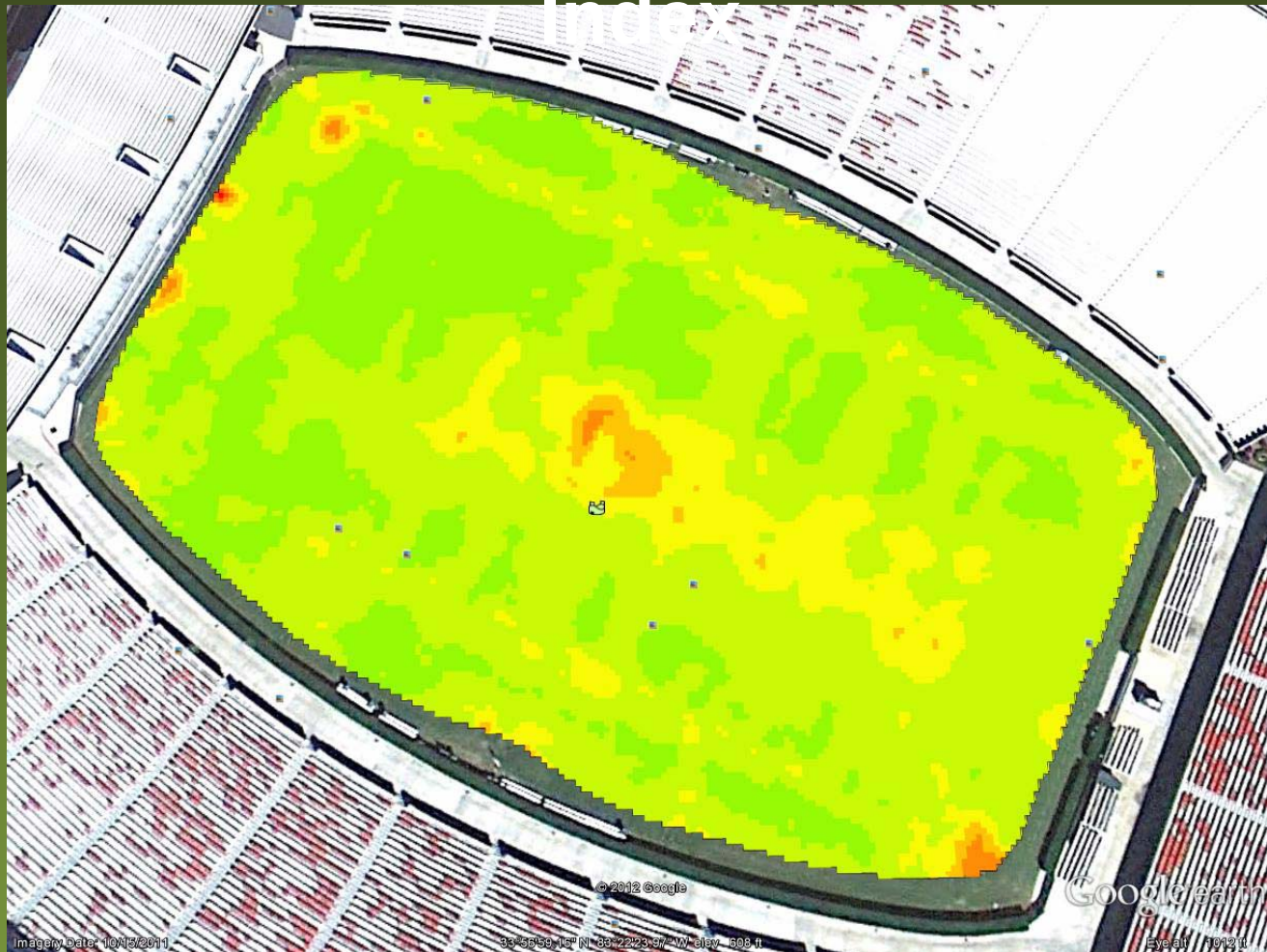


Site-Specific Fertilization

特定地區的施肥

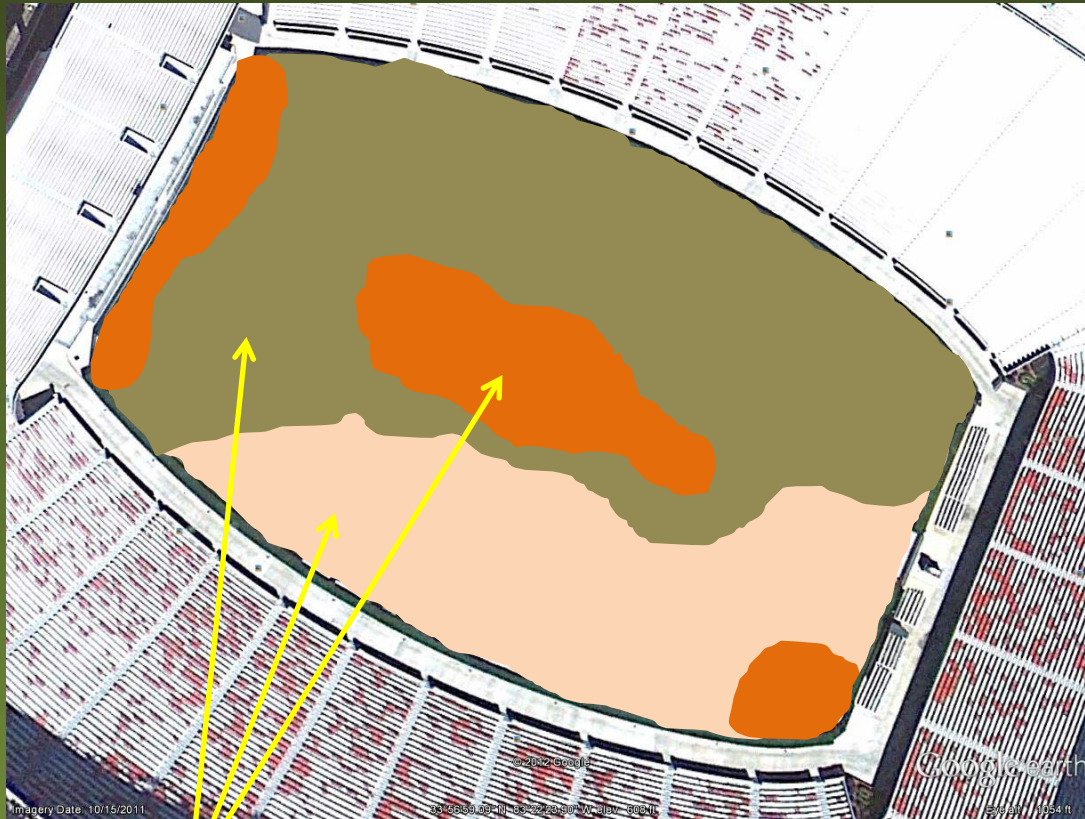
NDVI – Normalized Difference Vegetation

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Site-Specific Fertilization

特定地區的施肥



**3 SSMUs
identified**

- Identify Site Specific Management Units (SSMUs)

鑑定該地區特定的測量單位(SSMUs)

- Allow for variable rate fertilizer application

可用不同成份的肥料



Site-Specific Cultivation

特定地區的耕作

Current Sampling Practices

目前的取樣方法

- **Golf course superintendents don't check soil compaction levels on a regular basis**
- **Soil compaction meters can be expensive and difficult to insert into the soil surface**
- **Athletic field managers only take ½ dozen samples on a field to determine overall soil compaction**

高爾夫球場總監並不定期檢查土壤板結情況

– High time/labor/cost requirements to sample

– 多時間/人力/成本以進行採樣

土壤板結探測儀可以很昂貴，難以插入土壤表面

場地管理人員只在場內採取**12**樣本以確定總體土壤板結程度

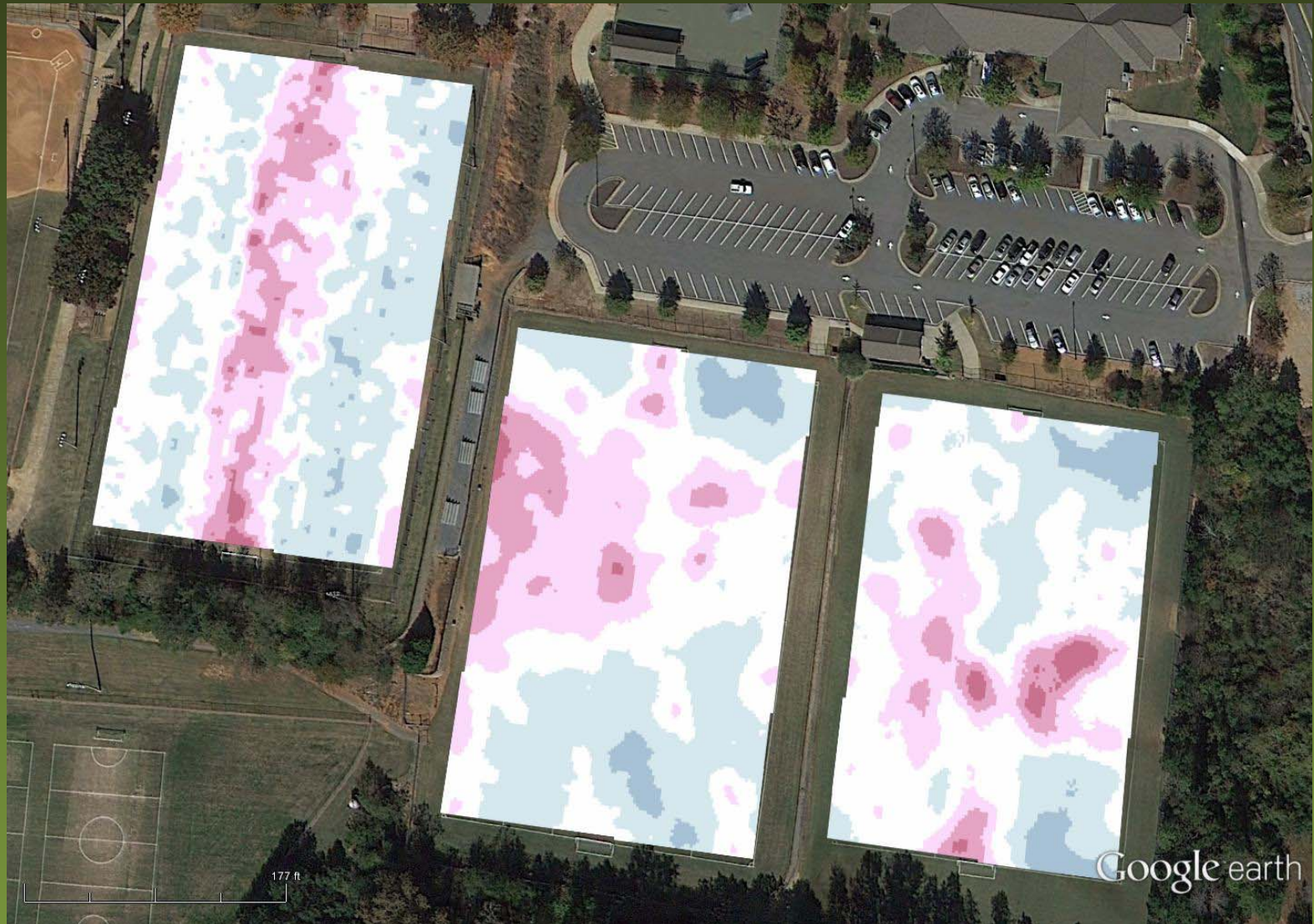
Previous Sampling

以前的樣本採集



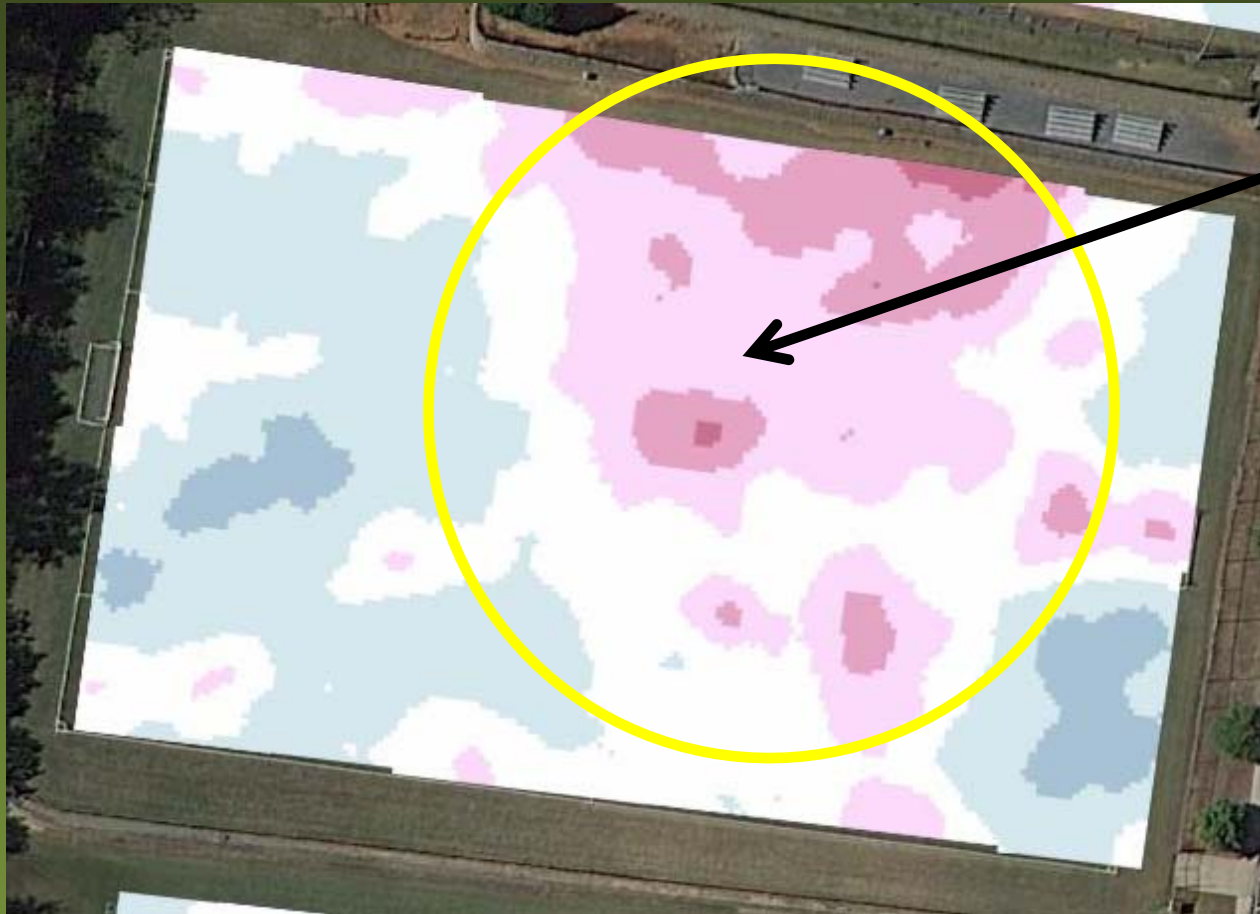
Site-Specific Cultivation

特定地區的護養



Site-Specific Cultivation

特定地區的護養



Area of
high soil
compacti
on

泥土高度板
結地區

Site-Specific Cultivation

特定地區的護養



**Identify 2
SSMUs to
manage
soil
compacti
on**

鑑別2種
SSMUs 管理
土壤板結

UGA Soil Compaction Research

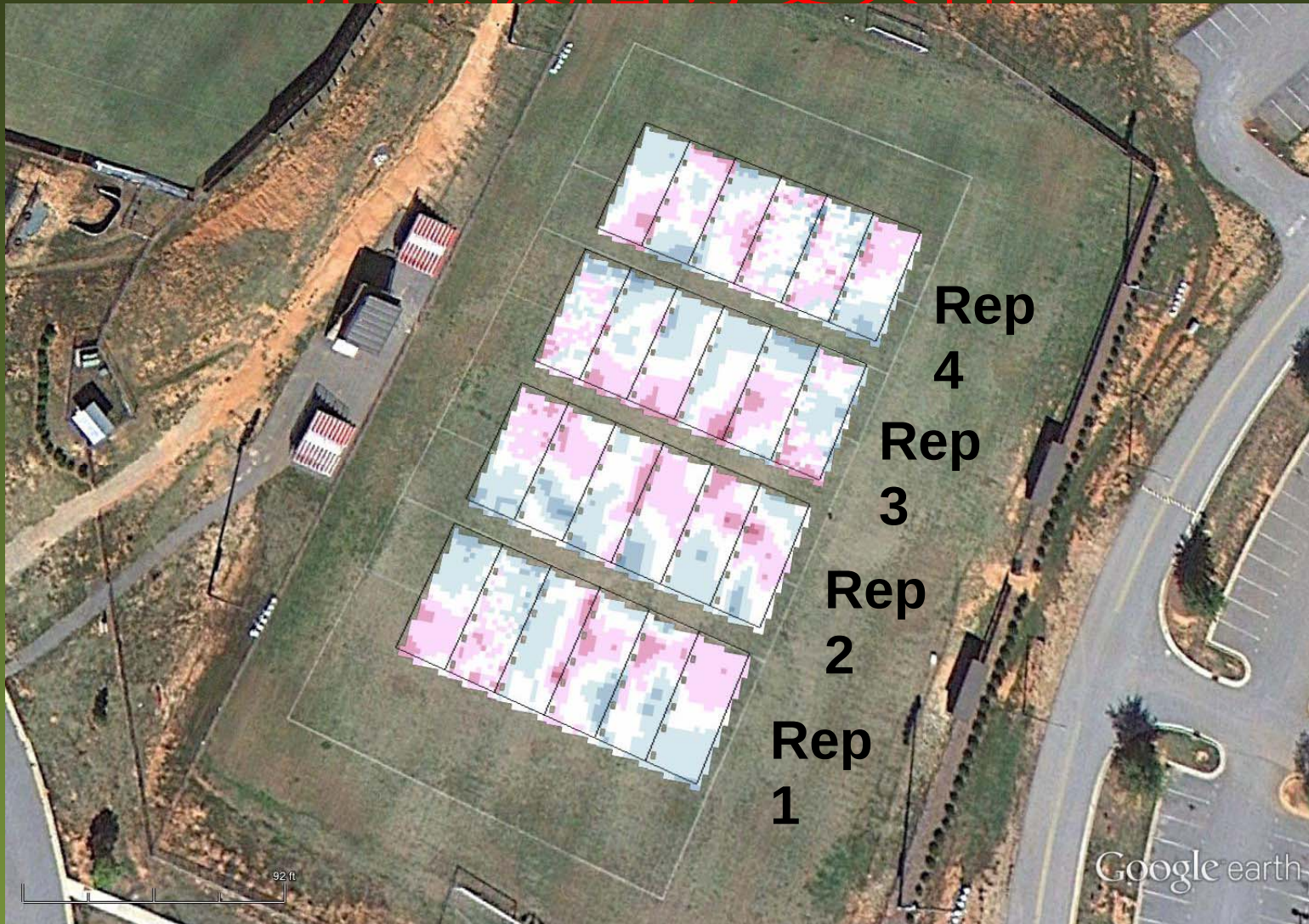
喬治亞大學泥土板結的研究

- Evaluating timing and frequency of cultivation events on soil compaction
 - 評估耕作時間和頻率對土壤板結的影響
- 4 soil-based athletic fields
 - 四種不同土質的運動場
- Map each field prior to cultivation treatments
 - 耕作前對場地進行繪圖



Soil Compaction Variability

泥土板結的變異性



Cultivation Treatments

護養處理

No

Aerification

Aerification 1x -

April

Aerification 1x -

July

Aerification

2x

Aerification

3x

Aerification

4x



UGA Soil Compaction Research

喬治亞大學泥土板結的研究

- Each field will be mapped again during the fall and again the following spring

每年秋、春二季為每個場地作投映繪圖

- Maps will be compared back to those created at trial initiation to determine the efficacy of each treatment

地圖將會與在預試中的結果比較以確定每項處理的效果

Conclusions 結論

- Precision Turfgrass Management

精密草坪管理

- offers another management tool to turfgrass managers seeking a greater understanding of spatial variability of their site and the implications for resource needs

為草地管理人員提供另一類型的管理工具以更多瞭解的他們的工作場所之空間的多變性及對及資源需求的影響

- The PTM area will develop over time, with new technologies incorporated

精密草坪管理的場地將隨著時間而發展,並加入新的技術

- However, there is considerable potential for this concept at the current state-of-the-science to address efficiency questions related to inputs of “where, when, and how much” on a more site-specific basis than current practices

然而,精密草坪管理的概念,在目前的科技水平上,應用於評估“何時何地及份量”的效率,未來仍有很大的發展空間



Questions?

問題?