Tracing the origin of cotton: a novel approach to increase transparency of cotton supply chains

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Introduction

Annually approx. 25 million tons of cotton are produced, which are used to make 50% of all clothes, household goods and other commercial products[1]. For the production of cotton, surface and ground waters are often diverted to irrigate cotton fields, leading to freshwater loss through evaporation and inefficient water management. This often has a severe impact on the environment, and more than 50% of the global cotton production area is under high physical water risk[2] (categories 4 and 5; see Fig. 1). Being able to determine geographic origin of cotton should lie in the interest of textile producer companies not only for quality reasons but also for reputational risks regarding the plants' consumptive water footprint. For this proof-of-concept study we concentrated on un-dyed cotton fibers of known country of origin. The aim of this work was to explore the potential for Isotope Ratio Mass Spectroscopy (IRMS) and trace element analysis to be utilized as a tool for cotton fiber analysis in an attempt to reveal discriminatory information on the provenance of cotton. Eventually this new technique may lead to predict the provenance of cotton from production areas which are characterized by high physical water risk.

Cotton plant with seed capsule. © WWF

Methods and Materials

55 raw cotton samples from 11 countries were received from the Bremen Cotton Exchange in 2019. Exact provenance of the material was not known, but year and country of origin and occasionally geographic subregions were curated. Number of samples per country varied between 1 and 15. All isotope and trace element analyses were carried out at the Scottish Universities Environmental Research Centre (SUERC), East Kilbride. Elemental analysis for 11 metals (Al, Cu, Ca, Fe, K, Mg, Mn, Na, Sr, Ti, Zn) has been conducted using ICP-OES. All stable isotope analyses (δ^2H, $\delta^{13}C$) were performed using continuous-flow isotope ratio mass spectrometry (CF-IRMS) and results are reported in δ notation[3]. Samples were corrected for exchangeable H using the comparative equilibration technique of Wassenaar and Hobson[4]. In order to assess precision of the analyses, we performed at least three replicate measurements for each sample. Analytical uncertainties, based on these replicate analyses were typically between 0.06‰ ($\delta^{13}C$), 1‰ (δ^2H) and varied between 0.19% (Zn) and 1.16% (Mn) in the trace elements.

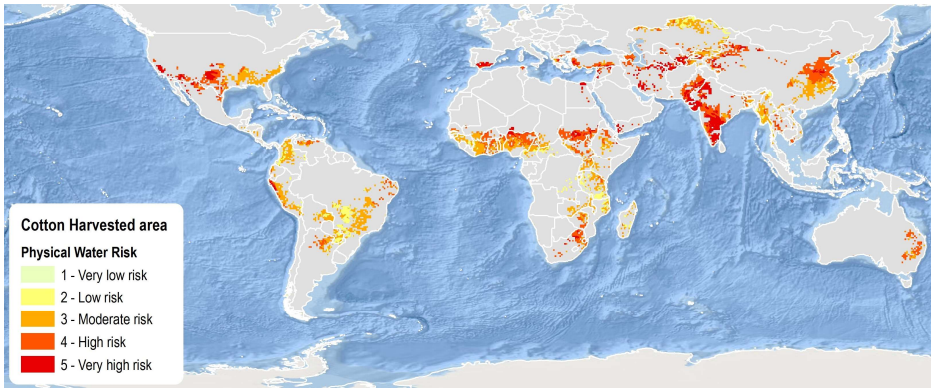

Figure 1: Cotton cultivation areas in different physical water risk categories.

Results and Discussion

All measured isotopic values, and particularly δ^2H, show a considerable range across the countries of origin (Fig. 2). Cotton from Uzbekistan is depleted and Indian cotton is enriched in the heavy hydrogen isotope. This is based on the fact that the hydrogen composition of cotton cellulose is triggered by combination of effects of temperature, precipitation amount and continentality. Country and sub-regional clusters are clearly visible in the isotope biplot (Fig. 2). Our results indicate that trace elements in cotton can be used to characterize certain regions: Mn – China (Fig. 3); Sr – Turkey and Uzbekistan (not shown). We randomly partitioned the reference samples ten times into a training (n=40) and a test (n=10) group and applied the *k*-nearest neighbor rule as the pattern classification algorithm. In order to avoid overfitting, we restricted the numbers of variables to five whereby the combination of δ^2H, $\delta^{13}C$, Sr, Mn, Zn showed the best output. On average, 72% of all cotton samples were correctly assigned to their country of origin (Tab. 1). Although the sensitivity for certain countries was lower, the predictive power of the model to assign cotton samples to their alleged places of origin is at least 2.5 times higher than the random case.

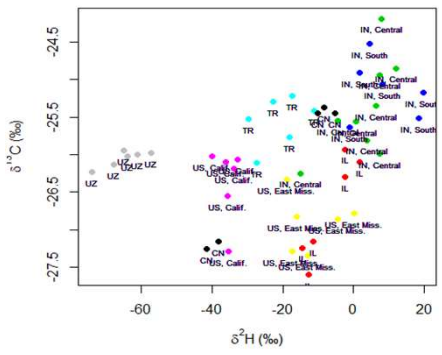

Figure 2: Cotton analyzed by IRMS to determine spatial clusters. Country codes are according to the ISO Alpha-2 code.

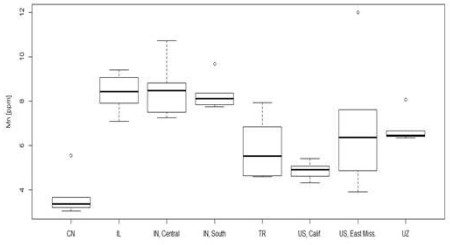

Figure 3: Concentration of Mn in cotton samples from different countries.

Table 1. Results of cross-validation across all reference samples which involved the determination of origin.

Country	Sensitivity	Apriori probability
China	66%	12%
Israel	77%	13%
India	75%	31%
Turkey	44%	9%
USA	61%	23%
Usbekistan	100%	12%

Conclusions

This initial study has demonstrated the potential for isotopic and trace metal analysis to be used as a promising tool to discriminate natural fibers of cotton based on geographical origin. The research confirmed that chemical profiling can be very useful in answering specific compliance questions whether a sample comes from a specific region or not. The approach can be used for geographic assignments within a probability context. The study has also shown that cotton production areas in high physical water risk regions, such as certain watersheds in India, China, Uzbekistan and Turkey are characterized by distinctive chemical and isotopic signatures. However, in order to draw general conclusions, sample effort from those countries needs to be increased to obtain a better understanding of seasonal variance of isotopic systems and trace metals' availability.

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