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Mind the gap: The challenges of sustainable forensic science service provision

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ABSTRACT

Recent worldwide humanitarian and security efforts reflect the growth of forensic science as a global practice supporting peace, prosperity, and justice. While the dominance of the Global North in published research and public attention may suggest that this practice is universally well-developed, many Global South jurisdictions are at a stark disadvantage in resourcing and technological capabilities. Continued development of forensic science as an international endeavour requires a narrowing of inequalities between jurisdictions, in line with the United Nations Sustainable Development Goals. Here we propose a framework of principles for the sustainable provision of transparent, high-quality forensic services meeting jurisdictional needs and limitations. We illustrate how this concept of 'frugal forensics' can be applied in the context of latent fingermark detection in two Global South jurisdictions, and how quality assurance frameworks can be developed to support this service.

1. Introduction

Forensic science has become a global practice going beyond its traditional province of supporting criminal investigations and the justice system to include humanitarian, peace, and security dimensions [1–4]. Collaboration in worldwide humanitarian efforts such as disaster victim identification in Thailand [5], post-conflict peacebuilding in Uganda [6], and management of highly infectious human remains in West Africa [7] are tangible examples. The global interconnectivity of these dimensions is reinforced by international organisations leveraging the power of collaboration and partnerships across the forensic community. This includes INTERPOL, the United Nations, and the International Organization for Standardisation (ISO) establishing various working groups aimed at developing international forensic science standards or guidelines for best practice [8]. This prompts reflection on the contribution of forensic science to sustain peace and justice both locally and globally. In other words, how does forensic science align with the global endeavour for peace and prosperity for humanity and the planet?

The United Nations Sustainable Development Goals (SDGs) (see Table 1) were universally adopted by United Nations Member States in 2015 [9]. The SDGs aimed to build a set of shared global targets for a just and equitable world, decoupled from environmental degradation. The term 'sustainable development' predates the SDGs and is attributable to the Brundtland Commission [10], which defined sustainable development in 1972 as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". The 17 SDGs are intertwined, and the 'SDG 16 –Peace and Justice' goal implies forensic science service provision as an essential service in achieving sustainable development. The pursuit of justice is not only worthy in its own right, it is also crucial in eliminating violence against women and girls [11] (SDG 5 – Achieve gender equality and empower all women and girls) and reducing inequality through provision of accurate evidence (SDG 10 – Reduce inequality within and among countries). Pervasive in the SDGs are the unique requirements of the Global South, which deserve special attention and consideration.

At the heart of the SDGs is the drive to reduce inequalities between nations and to transfer resources, knowledge, technology, and capability to the Global South. The denominations 'Global North' and 'Global South' are not geographic labels, but instead relate to socio-economic development and global influence [12]. The Global North is usually equated with technically developed and well-resourced countries, whereas Global South often denotes politically or culturally marginalised regions with comparatively limited income. Adaptation of cost-effective, fit-for-purpose and sustainable forensic practices recognises the unique conditions of the Global South against the backdrop of the Global North best practices and standards.

To understand the potential of forensic science as a driver for a sustainable future, we must first examine the status quo of forensic science provision around the world. A Scopus bibliometric search of articles using "forensic science" as a search term reveals that the space is dominated by literature emanating from the Global North (Fig. 1). A similar conclusion may be drawn from a more detailed recent study [13] examining research trends in the area of forensic fingermark detection and interpretation. The research hegemony, resourcing, and advanced capabilities of the Global North may convey the view that forensic science provision is globally well-developed. However, the stark reality is that the majority of Global South nations face substantial obstacles in forensic science service provision in comparison to the Global North. For example, literature reveals that challenges of the Global North revolve around high-level issues such as forensic backlogs [14,15], human bias or error influencing decision-making [16–18], and the need for evaluative and activity level reporting [19,20]. By contrast, the Global South

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Table 1
The United Nations Sustainable Development Goals [9].

Goal Number	Goal Name	Goal Description
SDG 1	No Poverty	End poverty in all its forms everywhere
SDG 2	Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG 3	Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages
SDG 4	Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG 5	Gender Equality	Achieve gender equality and empower all women and girls
SDG 6	Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all
SDG 7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG 8	Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG 9	Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation
SDG 10	Reduced Inequalities	Reduce inequality within and among countries
SDG 11	Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG 12	Responsible Consumption and Production	Ensure sustainable consumption and production patterns
SDG 13	Climate Action	Take urgent action to combat climate change and its impacts
SDG 14	Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG 15	Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG 16	Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG 17	Partnerships for the Goals	Strengthen the means of implementation and revitalise the global partnership for sustainable development

faces fundamental resourcing issues such as a lack of DNA or fingerprint databases [21,22], inadequate training [23,24], and supply chain problems [25,26]. It is hence unsurprising that the limited forensic research literature from the Global South largely focuses on the challenges around developing and strengthening fundamental forensic science capability and service provision.

A further layer of complexity is that each country in the Global South contends with its own unique challenges that may influence the development, implementation, management, and governance of quality forensic service delivery systems [1,8,27]. This makes international standards of uniformity, such as accreditation, notional for some jurisdictions. Ensuring robustness of the systems surrounding the forensic process is an essential element to the successful implementation of methodologies and service models. The development and maintenance of quality management (QM) systems to support consistency, accuracy, transparency, and continuous improvement in service delivery is widely recognised as key to quality assurance [28–31]. Although the need for scientifically valid methods and recognised QM systems cannot be understated, the regional models of forensic science provision are inevitably linked to local factors and demands. This raises the question of how the Global South can adapt forensic practices suited to their locality and still maintain fit-for-purpose quality benchmarks. Altogether, these issues highlight the gap between Global North and South and present a pivotal test to the provision of quality forensic science as a global endeavour.

Here we propose an example, demonstrated through evaluation of sustainable fingermark detection protocols, of how Global South jurisdictions can adapt to the challenges of their locality, towards sustainable provision of forensic science services. This can be achieved by recognising vulnerabilities within the process and building resilient capacity through delivery of innovative, simple and economical services meeting fit-for-purpose quality benchmarks, rather than striving for the provision of technologies or techniques outside of available means or capabilities. This approach follows a concept we refer to as ***frugal forensics***, defined as the development of resilient and economical forensic science provision that meets the needs of society without compromising quality and safety. This concept is derived from a combination of frugal innovation [32] and the Brundtland Commission [10] definition of sustainable development. Frugal forensics is based on three core principles; Resilient, Economical and Quality, and six attributes; Performance, Accessibility, Availability, Cost, Simplicity and Safety (PAACSS) (Fig. 2), which underpin the sustainable provision of forensic science services. At the heart of this approach is shifting the focus from 'pure' performance to a holistic consideration of jurisdictional vulnerabilities, while still ensuring that risks or limitations are recognised and documented to ensure transparent, high-quality service provision.

While it may not have been explicitly defined previously, sustainable forensic science provision is not a new concept, as by nature and necessity it is embraced in Global South countries due to their unique needs. However, its development thus far has been piecemeal and ad hoc. The challenge to be faced is for it to be systematically integrated and aligned to international standards as far as can be practically achieved. This paper illustrates how this concept can be applied through examination of the context of two Global South jurisdictions' latent fingermark detection services. In addition, a tool is proposed for evaluative assessment of a method's sustainability in light of 'frugal forensics' principles and demonstrated through its application to one of these jurisdictions. Finally, a discussion is presented regarding how quality assurance frameworks can be developed to support sustainable forensic science service. Although this approach focusses on fingermark detection, the considerations raised in terms of the economics, resilience and quality are also applicable to sustainability of the broader forensic science service provision. One of the objectives of this discussion is to promote an inclusive and outward looking forensic science, particularly at this juncture when the forensic community is re-examining the state and definition of forensic science [33].

2. Latent fingermark detection service provision - two Global South jurisdictions' perspectives

The successful detection of latent fingermarks is a crucial forensic tool used in humanitarian and criminal investigations globally [13,34]. Over the last two decades there has been a significant increase in research improving existing techniques and developing novel techniques [13,35–37]. However, this research has largely focussed on improving performance relating to the quality and quantity of fingermarks detected, without considerations of sustainability or applications in jurisdictions with limited resources. Implementation of these techniques in operational settings may not be feasible in Global South countries due to cost, availability, or accessibility of resources and appropriately trained staff. Below we examine the constraints of two Global South jurisdictions (Seychelles and Brazil) in the domain of latent fingermark provision and discuss responses in line with the frugal forensics concept.

Seychelles is an archipelago of 115 islands in the West-Indian Ocean spread over a vast sea area of 1.4 million square kilometres, covering a total land mass of 444 square kilometres. It is the smallest African state

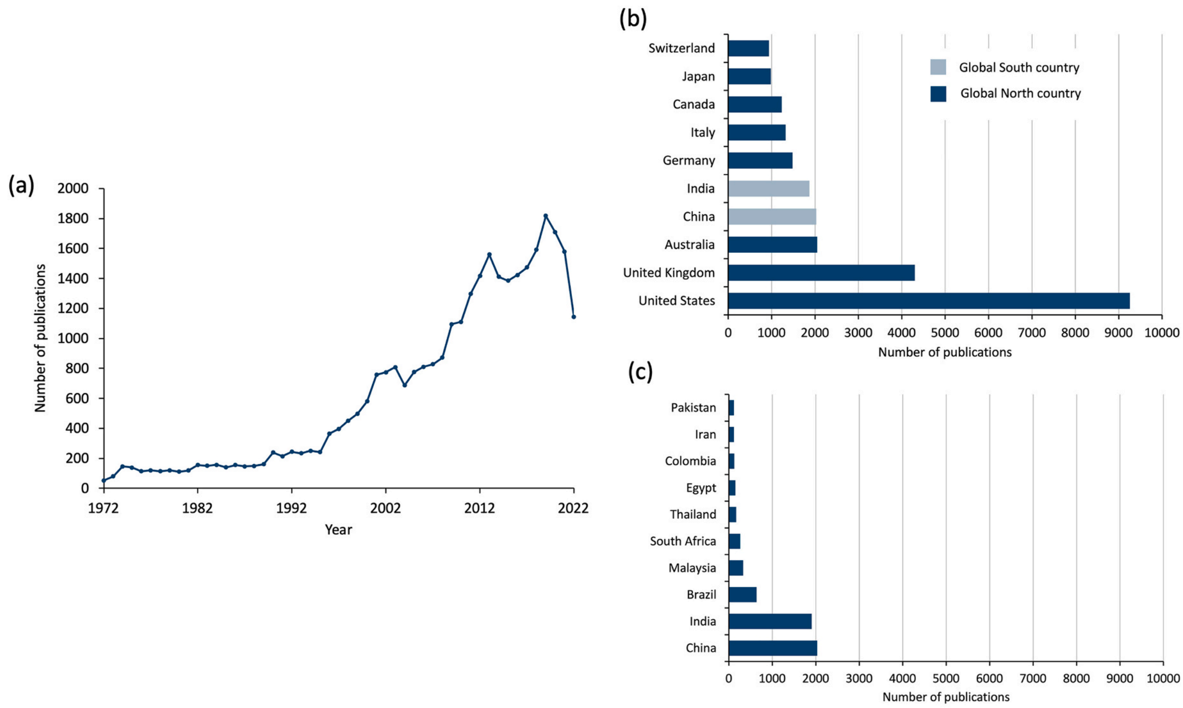

Fig. 1. Number of publications on "forensic science" in a simple Bibliometric search on Scopus for the (a) Total papers 1972–2022 (b)Top 10 countries and (c) Top 10 Global South countries.

Fig. 2. Principles and attributes of sustainable forensic science provision.

with a population of approximately 100,000 [38] and a fragile economy largely based on tourism. The potential socio-economic impact of crime on a small island community and fragile economy has led the Government to substantially invest in strengthening forensic science service provision, including fingermark recovery and detection capabilities. The fingermark section established in 1962 was the first formal local forensic science service and is strongly influenced by the United Kingdom model; Seychelles being a former British colony. This is evident with most of the personnel trained in the United Kingdom and the use of the "Fingermark Visualisation Manual" published by the UK Home Office Centre for Applied Science and Technology (CAST) [39] as the basis for applying fingermark detection methods.

Relative to population size, Seychelles can be considered to have adequate resources and locally trained staff within a unified forensic science service, which operates on a hybrid of local service provision and overseas outsourcing under the auspices of the Seychelles Police. However, Seychelles is particularly vulnerable to supply chain disruption as it sits at the end of the commercial supply chain due to its geographically remote location [25]. As an example, the common carrier solvent HFE-7100 (methyl nonafluorobutyl ether) used in amino acid detection reagents is both expensive (ca. USD$240 per litre) and prone to restricted supply [40,41] due to the contribution of fluorinated greenhouse gases to climate change. This risk is exacerbated as it is a single-source proprietary solvent from 3 M™ Novec™ [42] under demand from multiple industries. It follows then from the perspective of a low-budgeted laboratory in a remote location that the reliance on HFE-7100 poses a high risk to service continuity. In the context of frugal forensics, modifying detection reagents to use an alternative carrier solvent that is inexpensive and less susceptible to supply disruption would be a step towards more sustainable and resilient development of the latent fingermark service.

Brazil is a vast country in South America with a land mass of 8.5 million square kilometres and diverse environmental conditions ranging from dry regions in the arid Caatinga to the humid Amazon rainforest. Globally, it is the fifth largest and sixth most populous country, with a current population of about 216 million people, 87% of whom live in urban areas [43]. Brazilian forensic science service provision is divided amongst 28 government agencies, including the federal police. There are 27 autonomous governance states in Brazil, and each state's forensic science service is subordinated to the local state governments. The services and facilities are predominantly centralised in the capital cities or at a federal police superintendence, with a comparative lack of resources at the regional level. In a Brazilian government report [26], the lack of resources and training in regional areas were underlined as the primary challenges in fingermark provision, leading to a high proportion of unsolved murder cases as the perpetrators are not able to be identified [44].

Brazil also suffers from aggressively high inflation for goods and services [45]. Although exacerbated by COVID-19, this inflationary pressure arrived before the pandemic and contributes to high levels of social inequality leading to increased violence reflected in government reports over the 20 years. In the face of this economic climate, one of the government strategies to strengthen forensic science service provision was the investment in key forensic science research areas. Brazil currently accounts for only 1.5% of scientific production across international journals [46]. The Brazilian main scientific research funding agencies have been issuing public notices to support forensic science services [47,48]. However, the unstable funding of outcomes and current freeze on research incomes make the state of Brazilian research increasingly fragile [49,50]. Therefore, there is a need for frugal forensics to address the limited resources and training available in remote jurisdictions. One potential avenue is a frugal forensic approach using natural products to develop simple, low-cost, non-toxic and readily available protocols in a Brazilian context.

Several papers have been published on using naturally occurring substances for latent fingermark detection [51–56]. This has included treatments as diverse as amino acid reactive stains [51,52], spice powders and extracts [57,58], mineral pigments [56] and flours [59]. For example, genipin is a natural blue-violet dye extracted from gardenia fruits, used in food and fabric colourants, and considered safe and environmentally friendly [60]. The genip tree (*Genipa americana* L.) is native to the Amazon biome [61] and the indigenous populations prepare the dye from the fruit to paint their bodies and ornaments [61]. Genipin has been reported to have good potential as a fingermark reagent, reacting with amino acids to produce a blue-coloured complex with fluorogenic activity when illuminated at 590 nm and viewed with a barrier filter above 630 nm [51,52]. Alternatively, turmeric is a cheap, non-toxic and easily accessible common household ingredient that has been reported as a latent fingermark powdering technique [57]. Genipin and turmeric are potential candidates for the development of sustainable protocols for regional areas in Brazil where resources are lacking. These methods may be less effective in pure performance terms than analogues used in the Global North; however, this approach provides a fingermark protocol option rather than absence of it.

3. Evaluation of sustainable protocols for latent fingermark detection

Regardless of the local challenges, the development of protocols for forensic science service provision must be carried out in a manner reflecting international best practices and minimum requirements. For latent fingermark detection, the International Fingerprint Research Group (IFRG) guidelines [62] provide an objective evaluation and reporting framework for performance assessment of new or modified methods. The guidelines specifically recommend the testing of methods in the environment in which they are to be operationally used, aligning with the concept of frugal forensics as 'meeting the needs' of the locality. The recommendation for local validation can be seen as an extension of this recommendation that assesses not only performance but the sustainability of the method in consideration of local challenges. The IFRG guidelines recommend a grading system [63,64] to assess performance, and using this idea we suggest a similar grading tool (Table 2) for the assessment of the suitability of a method or service. This works by using the grading system to evaluate each of the six PAACSS attributes of frugal forensics to determine whether a forensic method or service can be considered sustainable within a specific context.

As an example, the evaluation can be applied to a recently published work [65] comparing different 1,2-indanedione-zinc (IND-Zn) formulations in the context of supply chain and resource-limited constraints relevant to the Seychelles. IND-Zn is recognised as one of the most effective treatments for the detection of latent fingermarks on porous

Table 2
Comparative score assessment tool.

Comparative Score for each of PAACSS		Recommendation Score (combined total)	
Score	Description	Total Score	
+2	Major benefit of alternative method	≥2	Strongly recommended
+1	Significant benefit of alternative method	1	Recommended
+0.5	Minor benefit of alternative method	0.5	Maybe recommended
0	No difference between methods		
−0.5	Minor benefit of nominal method	<0	Not Recommended
−1	Significant benefit of nominal method		
−2	Major benefit of nominal method		

substrates. The referenced study focussed on identifying an effective and sustainable formulation, improving on the current ninhydrin method used by the Seychelles Police. It was demonstrated that the different formulations of IND-Zn are of comparable performance (Fig. 3) when compared head-to-head across five substrates, including depletion series. A depletion series is a successive deposition of fingermarks on a surface intended to produce a gradual decrease in the deposited residue in order to test the sensitivity of the development technique [63]. The fingermark halves were graded according to the quality of the marks using the UK CAST assessment scale [63] (Table 3) and for comparison purposes the grades were classified into 3 groups [66].

Here we use the assessment tool (Table 2) to compare IND-Zn formulations employed by the UK Centre for Applied Science and Technology (CAST) [67] as the nominal method, against a modified formulation used by the German Bundeskriminalamt (BKA) [68]. The main difference between the two formulations is the carrier solvent; CAST uses HFE-7100 which poses a major supply chain risk as outlined in the preceding section, while BKA uses petroleum spirit with a boiling point (bp) of 40–60 °C and is a readily accessible solvent providing a major advantage in reducing the supply chain risk. The difference in solvents also leads to a major variation in the cost of the respective formulations (Fig. 4).

Due to the comparable performance between the formulations, a score of 0 was attributed to performance while a score of +2 was given for cost, given the major economic benefit of the BKA formulation for a low-budgeted laboratory (Table 4). Considering the lower supply chain risk and the significant flammability risk of petroleum spirits in comparison to HFE-7100, a score of +2 and −1 was attributed to Accessibility and Safety, respectively. While the flammability risk of petroleum

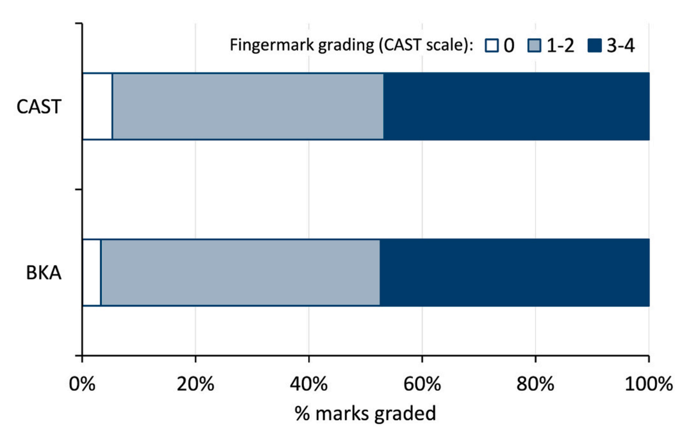

Fig. 3. Summary of fingermarks grading results categories into no marks detected (0), detected but not suitable for comparison (1–2) and suitable for comparison (3–4) showing comparable performance between the two formulations.

Table 3
Fingermark grading scale [63] and classification [66].

Grade	Friction ridge detail developed	Classification
0	No evidence of mark	No fingermarks detected
1	Weak development; evidence of contact but no ridge detail	Detected, but not suitable for comparison
2	Limited development, ridge details present; but probably cannot be used for identification purposes	Detected, but not suitable for comparison
3	Strong development more than 2/3 of fingermark continuous ridges	Suitable for comparison
4	Very strong development: full ridge details	Suitable for comparison

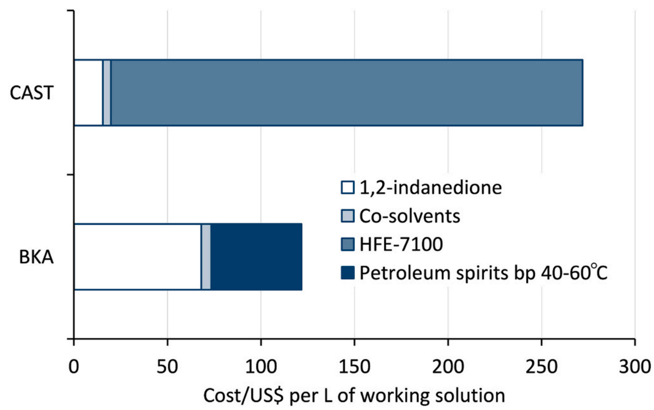

Fig. 4. Cost analysis of 1,2-indanedione-zinc formulation based on the amount of reagents used in 1 L of solution showing the carrier solvent as the major cost factor between the two formulation.

spirit is low when used in a properly fitted chemistry laboratory, it has been assumed that such resources are not readily available, so consequently a score of −1 was assigned for Safety. Compared to the CAST method, the BKA method does not require an oven for sample processing. This is a significant benefit for a low-budgeted laboratory and consequently a score of +1 was attributed to Simplicity.

Based on the assessment tool, a total recommendation score of +3.5 was achieved, indicting a strong recommendation of the BKA method as a more sustainable formulation when compared against the CAST method in the context of Seychelles challenges. While this tool can be primarily used for decision making, it can also be beneficial in identifying areas of a method or service that require modification to achieve sustainability. Similarly to the hierarchy of controls in managing health and safety risks, a framework could be put in place for addressing factors contributing to negative scores, and subsequently re-evaluating sustainability of the modified approach using the tool. Altogether, this provides not only an objective and holistic evaluation in consideration of the jurisdiction-specific challenges, but transparency in the processes used to evaluate and select methods for implementation. This is crucial to demonstrate the validity and weighting of results provided to end-users of forensic information, and forms a critical component of quality assurance in forensic science service provision. As highlighted previously, quality assurance in the Global South can be challenging and this is further discussed below.

4. Assuring quality in sustainable forensic science service provision

Quality management (QM) systems based on competency-based standards such as ISO/IEC 17025 have been developed, implemented, and adopted by numerous forensic science facilities worldwide. Independent recognition of compliance with these standards via accreditation has become mandatory in certain jurisdictions [69]. The process of independent expert assessment for accreditation purposes has been argued as critical to ensuring minimum standards are met [30,70–72]. For forensic science to operate as a global endeavour where borders are no longer a barrier to intelligence-led investigation of crime, harmonisation of the information being shared and the quality systems used to produce it is key [73]. However, there are issues associated with the accreditation process that must be considered, particularly when assessing the value of this process in the context of sustainable service provision for facilities challenged by remote geography, limited access to peak technology or restricted budgetary support [74].

The drive for accreditation of critical service providers even in resource-limited or challenging environments is not unusual. In the African region for example, extensive reviews of critical health care services in resource-poor settings has led to collaborative strategic planning efforts to assist developing countries in fulfilling international quality system standards, such as ISO 15189 [75,76]. In Thailand, international accreditation of laboratory services within the health care sector was similarly challenging, in part due to the remote locations of some laboratories. This led to the development of a feasible, affordable, and sustainable national strategy to address the gap between current and best practice [77]. In addition to innovation and improvement of protocols, the key to overcoming such challenges hinges on demand from within the field itself, coupled with the necessary political support [78]. Within the principles of sustainable practice, we need to look beyond a 'one-size-fits-all' approach to accreditation as the sole answer to achieving this goal.

As demonstrated in the health care setting [76], the importance of regional and international networks for promoting, developing, and implementing sustainable quality and ethical standards cannot be underestimated. Forensic practitioners have an obligation to the entire judicial system as impartial and accurate providers of information [79]. Moreover, the establishment of professional bodies adding accountability of practitioners to professional and ethical standards through adherence to Codes of Practice, has been identified as a key strategy towards transparency and ethical provision of forensic service in regions such as South Africa [70].

Discussions on the suitability of the predominant accreditation standards currently used across forensic science disciplines have already been noted in international reports and inquiries (e.g. Ref. [14]). In recent years, the development of forensic-specific standards such as AS 5388 and ISO 21043 has begun to address some of these shortcomings [8]. Supplementary guidelines for best practice in forensic science, outside of those produced by organisations such as the ISO, represent a significant and valuable resource to service providers worldwide. In regions where access to assessment by accrediting bodies may be limited, or where regional professional networks are undeveloped, guidance on the implementation of discipline-specific best practice from recognised subject matter expert advisory groups in other regions (even those based in the Global North, such as the Organization for Scientific Area Committees, United Kingdom Forensic Regulator and the Australia New Zealand Policing Advisory Agency National Institute of Forensic Science) can be accessed, interpreted based on the local service

Table 4
Comparative scoring results for 1,2-indanedione-zinc BKA formulation against nominal method CAST.

Nominal method (CAST)	Performance	Accessibility & Availability	Cost	Safety	Simplicity	Total Score	Recommendation
BKA	0	+2	+2	−1	+0.5	+3.5	Strongly recommended

provision environment and developed for implementation. Global South jurisdictions may enlist the support of the larger networks, such as the International Forensic Strategic Alliance, in their validation of adapted best practice systems and methodologies through consensus studies and independent review.

The professional practices comprising a quality management system will be moot if the underlying validity of the techniques and methodologies in use is in question [15]. This emphasises the importance of research and development in strengthening the provision of forensic science and its outcomes [33,80]. The literature suggests several roadblocks to the successful widespread adoption of a research culture in forensic science [81,82], such as insufficient time or a lack of in-house research experience. It is evident that overcoming these barriers, particularly those to the operationalisation of research outcomes, plays a crucial role in the sustainability of quality practices in global forensic science. It is in this area that the forensic science providers of the Global South may well inform and lead the development of sustainable practice in forensic science service provision. Research initiatives to support sustainable service provision, such as those detailed in the sections above and born of necessity due to resource limitations (whether they be geographical, economic or environmental), will provide invaluable perspectives on forensic capability under challenging conditions. As best practice guidance developed by the Global North may be interpreted and adapted for a Global South environment, so may research into and validation of economical and fit-for-purpose scientific methodologies addressing localised issues in the Global South be adapted into forensic science service provision in the Global North. Not only does such an approach align with the international concern for the empirical validation of forensic techniques in assuring the quality of forensic science practice, but (and perhaps more importantly) it actively integrates contributions of the Global South forensic community in the advancement of sustainable forensic practice promoting continuous improvement and the assurance of robust, quality service provision.

5. Conclusion

Forensic science is now a global enterprise with an expanded focus to include roles in humanitarian, peace-keeping and security environments. This bestows an obligation to be aware of, aspire to, and deliver service provision strategically aligned with the SDGs. Raising the profile of the SDGs in the context of forensic science is timely, given the recent international reflection on the core principles of forensic science instigated through the Sydney Declaration [33]. The Declaration outlines a set of foundational principles for forensic science, designed to underpin practice. However, it also invites further debate and modification as part of the ongoing discussion to define and direct forensic practice into the future. We assert that the sustainable provision of forensic science must become a critical element of this international discourse. As a community, forensic science has been proactive in the development and adoption of new technologies and techniques, information sharing and data exploitation. The time has now come for us to bring together the combined knowledge of the Global North and South forensic communities with the goal of assuring sustainable, quality forensic science service provision on an international scale.

From the Global South perspective, we need to consider the breadth of disparity and challenges between the regions and communicate with experts and practitioners on the ground to identify vulnerabilities and opportunities to harness the synergetic effect towards a sustainable provision of forensic science. Additionally, such an exercise may shed more light on the many and varied reasons for the gap, which require further research. Currently, as part of a study at Curtin University, research is underway surveying Brazilian fingerprint experts on existing service provision capabilities and challenges. The information collected will feed into the identification and development of techniques and processing protocols that are suitable and sustainable for Brazil, but likely to have relevance to other jurisdictions.

Through an awareness of the principles of global sustainable development; investigation into and application of attainable, fit-for-purpose methodologies under the banner of 'frugal forensics'; and a practical, collaborative approach to attaining consistency in forensic quality management practices, forensic agencies worldwide may enter a new age of global partnership in the provision of service to advance justice and aid the public good, for the present and future generations to come.

CRediT authorship contribution statement

Jemmy Bouzin: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing. **Thais Lópes:** Conceptualization, Writing - Original Draft, Writing - Review & Editing. **Anna Heavey:** Conceptualization, Writing - Original Draft, Writing - Review & Editing. **Jessie Parrish:** Conceptualization, Writing - Original Draft, Writing - Review & Editing. **Georgina Sauzier:** Conceptualization, Writing - Review & Editing, Supervision. **Simon Lewis:** Conceptualization, Visualisation, Writing - Original Draft, Supervision, Project administration.

Declaration of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Simon W. Lewis is a member of the editorial board of Forensic Science International: Synergy.

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References

[1] D.H. Ubelaker, The Global Practice of Forensic Science, John Wiley & Sons, 2015.
[2] M.V. Tidball-Binz, S. Cordner, Humanitarian forensic action: a new forensic discipline helping to implement international law and construct peace, WIREs Forensic Sci. 4 (1) (2021), https://doi.org/10.1002/wfs2.1438.
[3] A.S. Baharuddin, M.H. Ahmad, W.A.F.W. Ismail, L.A. Mutalib, M.A.W. Harun, Catalysing global peace through the strengthening of forensic science application in Sharī 'ah Law, Al-Shajarah: Journal of the International Institute of Islamic Thought and Civilization (ISTAC) (2019) 77–103.
[4] V.Y. Shepitko, M.V. Shepitko, The role of forensic science and forensic examination in international cooperation in the investigation of crimes, J. Natl. Acad. Legal Sci. Ukraine 28 (1) (2021) 179–186.
[5] INTERPOL Tsunami Evaluation Working Group," in "The DVI Response to the South East Asian Tsunami between December 2004 and February 2006," INTERPOL.
[6] J.J. Kim, An alternative approach to forensic anthropology: findings from northern Uganda, Afr. Conflict Peacebuilding Rev. 8 (1) (2018). http://10.2979/africonfpeacrevi.8.1.02.
[7] S. Cordner, H. Bouwer, M. Tidball-Binz, The Ebola epidemic in Liberia and managing the dead-A future role for Humanitarian Forensic Action? Forensic Sci. Int. 279 (Oct 2017) 302–309. http://10.1016/j.forsciint.2017.04.010.
[8] L. Wilson-Wilde, The international development of forensic science standards - a review, Forensic Sci. Int. 288 (Jul 2018) 1–9. http://10.1016/j.forsciint.2018.04.009.
[9] B.X. Lee, et al., Transforming our world: implementing the 2030 agenda through sustainable development goal indicators, J. Publ. Health Pol. 37 (1) (Sep 2016) 13–31. http://10.1057/s41271-016-0002-7.
[10] G.H. Brundtland, Brundtland report. Our common future, Comissão Mundial 4 (1) (1987) 17–25.
[11] O.O. Olusegun, O.S. Oyelade, Access to justice for Nigerian women: a veritable tool to achieving sustainable development, Int. J. Discrimination Law 22 (1) (2021) 4–29. http://10.1177/13582291211043418.
[12] D. Mitlin, D. Satterthwaite, Urban Poverty in the Global South : Scale and Nature, Routledge, London, 2013.
[13] A. Bécue, H. Eldridge, C. Champod, Interpol review of fingermarks and other body impressions 2016–2019, Forensic Sci. Int.: Synergy 2 (2020) 442–480, https://doi.org/10.1016/j.fsisyn.2020.01.013.

[14] Committee on Identifying the Needs of the Forensic Sciences Community and National Research Council, Strengthening Forensic Science in the United States: A Path Forward, 2009.
[15] President's Council of Advisors on Science and Technology, Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods: Report to the President, President's Council of Advisors on Science and Technology, Washington DC, 2016 [Online]. Available: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf.
[16] G. Edmond, et al., Thinking forensics: cognitive science for forensic practitioners, Sci. Justice 57 (2) (Mar 2017) 144–154. http://10.1016/j.scijus.2016.11.005.
[17] G. Ribeiro, J.M. Tangen, B.M. McKimmie, Beliefs about error rates and human judgment in forensic science, Forensic Sci. Int. 297 (Apr 2019) 138–147. http://10.1016/j.forsciint.2019.01.034.
[18] I.E. Dror, Cognitive and human factors in expert decision making: six fallacies and the eight sources of bias, Anal. Chem. 92 (12) (Jun 16 2020) 7998–8004. http://10.1021/acs.analchem.0c00704.
[19] D. Catoggio, J. Bunford, D. Taylor, G. Wevers, K. Ballantyne, R. Morgan, An introductory guide to evaluative reporting in forensic science, Aust. J. Forensic Sci. 51 (2019) S247–S251, sup.1, https://10.1080/00450618.2019.1568560.
[20] A. Biedermann, C. Champod, S. Willis, Development of European standards for evaluative reporting in forensic science, Int. J. Evid. Proof 21 (1–2) (2016) 14–29. http://10.1177/1365712716674796.
[21] D. Etin-Osa, E.-O. Ce, Forensic science and the Nigerian society, J. Nucl. Sci. (Seoul) 6 (1) (2019) 17–21.
[22] A.O. Amankwaa, E. Nsiah Amoako, D.O. Mensah Bonsu, M. Banyeh, Forensic science in Ghana: a review, Forensic Sci. Int. 1 (2019) 151–160. http://10.1016/j.fsisyn.2019.07.008.
[23] R.M. Mateen, A. Tariq, Crime scene investigation in Pakistan: a perspective, Forensic Sci Int Syner 1 (2019) 285–287. http://10.1016/j.fsisyn.2019.06.046.
[24] J.M. Nderitu, Analysing the Efficiency of Forensic Science Units within Kenya Police Service in Solving Crimes, University of Nairobi, 2018.
[25] J.T. Bouzin, G. Sauzier, S.W. Lewis, Forensic science in Seychelles: an example of a micro-jurisdiction forensic delivery system, Forensic Sci. Int.: Synergy 3 (2021/01/01/2021), 100139. https://10.1016/j.fsisyn.2021.100139.
[26] I.S.d. Figueiredo, A.C.C. Pareschi, Diagnóstico da perícia criminal no Brasil, 2013.
[27] W.P. McAndrew, M.M. Houck, Interpol review of forensic science management literature 2016–2019, Forensic Sci. Int.: Synergy 2 (2020) 382–388. http://10.1016/j.fsisyn.2020.01.007.
[28] M. Pereira, Quality assurance in forensic science, Forensic Sci. Int. 28 (1) (1985) 1–6. https://10.1016/0379-0738(85)90159-8.
[29] House of Lords, "Forensic science and the criminal justice system: a blueprint for change - Science and Technology Select Committee 3rd Report of Session 2017-19," House of Lords, London, 2019. [Online]. Available: https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/333/33302.htm.
[30] National Research Council, *National Research Council*, Strengthening Forensic Science in the United States : A Path Forward, National Academies Press, Washington, D.C., UNITED STATES, 2009. Washington DC.
[31] House of Commons, "Third Special Report of Session 2019-21: Work of the Biometrics Commissioner and the Forensic Science Regulator: Government Response to the Committee's Nineteenth Report of Session 2017-19," Science and Technology Committee: House of Commons, London, London, 2021. [Online]. Available: https://publications.parliament.uk/pa/cm5801/cmselect/cmsctech/1319/131902.htm.
[32] R.R. Basu, P.M. Banerjee, E.G. Sweeny, Frugal innovation, Journal of Management for Global sustainability 1 (2) (2013).
[33] C. Roux, et al., The Sydney declaration - revisiting the essence of forensic science through its fundamental principles, Forensic Sci. Int. 332 (Jan 11 2022), 111182. http://10.1016/j.forsciint.2022.111182.
[34] R. Lessig, M. Rothschild, International standards in cases of mass disaster victim identification (DVI), Forensic Sci. Med. Pathol. 8 (2) (Jun 2012) 197–199. http://10.1007/s12024-011-9272-3.
[35] S. Shahbazi, et al., Luminescence detection of latent fingermarks on non-porous surfaces with heavy-metal-free quantum dots, Forensic Chemistry 18 (2020), 100222.
[36] M. Tahtouh, J.R. Kalman, C. Roux, C. Lennard, B.J. Reedy, The detection and enhancement of latent fingermarks using infrared chemical imaging, J. Forensic Sci. 50 (1) (2005) JFS2004213–J2004219.
[37] A. Bécue, A.A. Cantú, Fingermark Detection Using Nanoparticles, CRC Press LLC, 2012, pp. 307–379.
[38] Seychelles National Bureau of Statistics. "Population and vital statistics December 2021." https://www.nbs.gov.sc/ (accessed Nov 2022.
[39] H. Bandey, S.M. Bleay, V.J. Bowman, R. Downham, V. Sears, H. Bandey (Eds.), Fingermark Visualisation Manual, Home Office CAST, United Kingdom, 2014.
[40] E.U. Regulation (, *No 517/2014 of the European Parliament* and of the Council of 16 April 2014 on Fluorinated Greenhouse Gases and Repealing Regulation (EC) No 842/2006, Off.J.Eur.Union, 2014, pp. 150 195–230.
[41] Defence Science, Technology Laboratory, Fingermark Visualisation Newsletter, October 2020.
[42] "3M™ Novec™ 7100 Engineered Fluid (2009)." [Online]. Available: https://multimedia.3m.com/mws/media/199818O/3m-novec-7100-engineered-fluid.pdf.
[43] Worldometer. https://www.worldometers.info/world-population/brazil-population/. (Accessed 21 November 2022).
[44] Relatório Nacional da Execução da Meta 2, Um Diagnóstico da Investigação de Homicídios no País, in: Brasília, Conselho Nacional Do Ministério Público, 2012.
[45] International Monetary Fund, Latin America hit by one inflationary shock on Top of another. https://www.imf.org/en/News/Articles/2022/04/15/cf-latin-america-hit-by-one-inflationary-shock-on-top-of-another. (Accessed 23 November 2022).
[46] J. C. d. C. O. N. Marco Antônio de Souza, Fingerprint analysis in Brazil: a bibliometric review 2010-2019, Brazilian J.Forensic Sci. Med. Law Bioet. 10 (3) (2021) 473–491, https://doi.org/10.17063/bjfs10(3)y2021473-491.
[47] Coordination for the Improvement of Higher Education Personnel. "Programa Ciências Forenses "Pró-Forenses"." (accessed 21 November 2022.
[48] Coordination for the Improvement of Higher Education Personnel. "Programa de cooperação acadêmica em segurança pública e ciências forenses." (accessed 23 November 2022.
[49] S.F. Ana Bottallo, Cuts in education paralyze payment of 200,000 scholarships in Brazil, in: Folha de São Paulo, 2022. https://www1.folha.uol.com.br/internacional/en/business/2022/12/cuts-in-education-paralyze-payment-of-200000-scholarships-in-brazil.shtml.
[50] J.P. Onoszko Jan, Brazil's education system in crisis as Bolsonaro takes aim at universities, France 24 (2022).
[51] Y.C. Joseph Almog, Myriam Azoury, Tae-Ryong Hahn, Genipin-a novel fingerprint reagent with colorimetric and fluorogenic activity, J. Forensic Sci. 49 (2) (2004) 255–257.
[52] Y.C. Genyia Levinton-Shamuilov, Myriam Azoury, Alan Chaikovsky, Joseph Almog, "Genipin, a novel fingerprint reagent with colorimetric and fluorogenic activity, part II: otimization, scope and limitations, J. Forensic Sci. 50 (6) (2005) 1367–1371.
[53] L.M. B, Luan F. Passos, Tais Poletti, Kristiane de C. Mariotti, Neftali L.V. Carreño, Carla A. Hartwig, M. Claudio, P. Pereira, Evaluation and characterization of algal biomass applied to the development of fingermarks on glass surfaces, Aust. J. Forensic Sci. 53 (3) (2021) 337–346, https://doi.org/10.1080/00450618.2020.1715478.
[54] S.N.A. Nur Fatin Nabihah Said, Yusmazura Zakaria, Revathi Rajan, Nurasmat Mohd Shukri, Nik Fakhuruddin Nik Hassan, Recycling potential of natural waste products in the development of fingerprint powders for forensic application, Malays. J. Med. Health Sci. 17 (4) (2021) 196–204.
[55] N.F.Z. Mahendran Sekar, Development of natural latent fingerprint powder from duran seeds - a green and effective approach in crime scene, Indo Amer. J. Pharm. Sci. 4 (8) (2017) 2362–2367.
[56] R.K.G. Pallavi Thakur, New development reagent for latent fingermark visualization: fuller's earth (*Multani Mitti*), Egypt. J. Food Sci. 6 (2016) 449–458, https://doi.org/10.1016/j.ejfs.2016.11.007.
[57] H.K. Rakesh K. Garg, Ramanjit Kaur, A new technique for visualization of latent fingerprints on various surfaces using powder from turmeric: a rhizomatous herbaceous plant (*Curcuma longa*), Egypt. J. Food Sci. 1 (2011) 53–57, https://doi.org/10.1016/j.ejfs.2011.04.011.
[58] V.S. Seerat, Lav Kesharwani, A.K. Gupta, Munish Kumar Mishra, "Comparative study of different natural products for the development of latent fingerprints on non-porous surfaces, International Journal of Social Relevance & Concern 3 (8) (2015) 9–12.
[59] A.K.K. Richa Rohatgi, New visualizing agents for developing latent fingerprints on various porous and non-porous surfaces using different household food items, Asian J. Sci. Appl. Tech. 3 (2) (2014) 33–38.
[60] R. Jelly, E.L. Patton, C. Lennard, S.W. Lewis, K.F. Lim, The detection of latent fingermarks on porous surfaces using amino acid sensitive reagents: a review, Anal. Chim. Acta 652 (1–2) (Oct 12 2009) 128–142. http://10.1016/j.aca.2009.06.023.
[61] G.G.G. Bernardo Tomchinsky, Almecina B. Ferreira, Food composition data: edible plants from the Amazon, Local Food Plants Brazil (2021), https://doi.org/10.1007/978-3-030-69139-4_13.
[62] International Fingerprint Research Group, Guidelines for the assessment of fingermark detection techniques, J. Forensic Ident. 64 (2) (2014) 174.
[63] V.G. Sears, S.M. Bleay, H.L. Bandey, V.J. Bowman, A methodology for fingermark research, Sci. Justice 52 (3) (Sep 2012) 145–160. http://10.1016/j.scijus.2011.10.006.
[64] C. McLaren, C. Lennard, M. Stoilovic, Methylamine pretreatment of dry latent fingermarks on polyethylene for enhanced detection by cyanoacrylate fuming, J. Forensic Ident. 60 (2) (2010) 199–222.
[65] J.T. Bouzin, A.J. Horrocks, G. Sauzier, S.M. Bleay, S.W. Lewis, Comparison of three active 1,2-indanedione-zinc formulations for fingermark detection in the context of limited resources and supply chain risks in Seychelles, Forensic Chemistry 30 (2022), 100439. http://10.1016/j.forc.2022.100439.
[66] S. Chadwick, S. Moret, N. Jayashanka, C. Lennard, X. Spindler, C. Roux, Investigation of some of the factors influencing fingermark detection, Forensic Sci. Int. 289 (Aug 2018) 381–389, https://doi.org/10.1016/j.forsciint.2018.06.014.
[67] N. Nicolasora, R. Downham, L. Hussey, A. Luscombe, K. Mayse, V. Sears, A validation study of the 1,2-indandione reagent for operational use in the UK: Part 1 — formulation optimization, Forensic Sci. Int. 292 (2018) 242–253. http://10.1016/j.forsciint.2018.04.046.
[68] I. Becker, M.-L. Heinrich, L. Schwarz, M. Bust, Process Instruction Indanedione/Zinc for the Visualization of Latent Fingermarks Version 4.1, Bundeskriminalamt, Wiesbaden, Germany, 2018.
[69] S. Doyle, A review of the current quality standards framework supporting forensic science: risks and opportunities, WIREs Forensic Sci. 2 (3) (2020/05/01 2020) e1365, https://doi.org/10.1002/wfs2.1365.
[70] A. Olckers, Z. Hammatt, Science serving justice: opportunities for enhancing integrity in forensic science in Africa, Forensic Sci. Res. 6 (4) (2021/10/02 2021) 295–302. http://10.1080/20961790.2021.1989794.
[71] A. Ross, W. Neuteboom, ISO-accreditation - is that all there is for forensic science? Aust. J. Forensic Sci. (2020) 1–13. http://10.1080/00450618.2020.1819414.

[72] Z. Pádár, M. Nogel, G. Kovács, Accreditation of forensic laboratories as a part of the "European Forensic Science 2020" concept in countries of the Visegrad Group, Forensic Sci. Int.: Genetics Suppl. Series 5 (2015/12/01/2015) e412–e413. https://10.1016/j.fsigss.2015.09.163.

[73] T. Raymond, R. Julian, Forensic intelligence in policing: organisational and cultural change, Aust. J. Forensic Sci. 47 (4) (2015/10/02 2015) 371–385. http://10.1080/00450618.2015.1052759.

[74] A.L. Heavey, Standards and accreditation, in: M.M. Houck (Ed.), Encyclopedia of Forensic Sciences, third ed., Elsevier, Oxford, 2023, pp. 617–625.

[75] J.N. Nkengasong, et al., Critical role of developing national strategic plans as a guide to strengthen laboratory health systems in resource-poor settings, Am. J. Clin. Pathol. 131 (6) (2009) 852–857. http://10.1309/AJCPC51BLOBBPAKC.

[76] G.-M. Gershy-Damet, et al., The world health organization african region laboratory accreditation process: improving the quality of laboratory systems in the african region, Am. J. Clin. Pathol. 134 (3) (2010) 393–400. http://10.1309/AJCPTUUC2V1WJQBM.

[77] N. Wattanasri, W. Manoroma, S. Viriyayudhagorn, Laboratory accreditation in Thailand: a systemic approach, Am. J. Clin. Pathol. 134 (4) (2010) 534–540. http://10.1309/AJCPZYY19WMKMAZT.

[78] W. Mansour, A. Boyd, K. Walshe, The development of hospital accreditation in low- and middle-income countries: a literature review, Health Pol. Plann. 35 (6) (2020) 684–700. https://10.1093/heapol/czaa011.

[79] G. Edmond, et al., Model forensic science, Aust. J. Forensic Sci. 48 (5) (2016/09/02 2016) 496–537. http://10.1080/00450618.2015.1128969.

[80] J.L. Mnookin, S.A. Cole, I.E. Dror, B.A.J. Fisher, The need for a research culture in the forensic sciences (in eng), UCLA Law Rev. 58 (3) (2010-2011 2010) 725–780 [Online]. Available: https://heinonline.org/HOL/P?h=hein.journals/uclalr58&i=731.

[81] J.G. Cino, Roadblocks: cultural and structural impediments to forensic science reform the future of crime labs and forensic science: criminal justice Institute symposium (in eng), Houst. Law Rev. 57 (3) (2019) 533–550, 2020 2019. 550.

[82] A. Ross, Integrating research into operational practice, Phil. Trans. Biol. Sci. 370 (1674) (2015/08/05 2015), 20140261. http://10.1098/rstb.2014.0261.

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