別紙-1

報告番号	※　　　　第　　　　号

主　論　文　の　要　旨

論文題目 Anthropogenic Disturbance of Mining Activities with Geomorphologic Change（地形変化を伴う資源採掘による人為的撹拌に関する研究）

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論　文　内　容　の　要　旨

Anthropogenic material flows & stocks are expanding at ever-increasing rates across the world, and their environmental and economic impacts draw more and more attention from industry, academia, policy-makers, economic, and environmental bodies. Stocks such as buildings, consumer products, factories, and infrastructure are essential foundations of society thus support economic activities and provide services. As the knowledge base regarding anthropogenic material flows & stocks expansion, it is important to not only comprehend the societal side of material consumption and stock growth but also its counterpart to the material balance—the natural environment from which the materials come from and to go. The globally common environmental impact, anthropogenic disturbance caused by material extraction is destructive and irreversible effect on natural environment, while only few studies mentioned relationship between material flow and its direct impacts on natural environment. In addition, due to difficulties of data procurement, and muted interest in materials which are considered low-value high volume, the environmental burdens especially related to construction minerals have received less attention so far despite the huge amounts involved. In this study, top-down method; statistics and bottom-up method; geographic information systems (GIS) with digital elevation model (DEM) and landcover datasets were employed, to form a common method of monitoring and measuring of the anthropogenic disturbance at mining and fill sites. This geographically explicit method allowed to directly point out location and volume of anthropogenic disturbance.

In chapter 1, academic and politic background of sustainable development, especially, which is related to material flows and stocks were introduced. We focused on issues accompanying huge amount of material consumption and accumulation in the socio-economic sphere is anthropogenic disturbance. The state of art researches and remote sensing techniques were introduced in this chapter.

In chapter 2, two types of DEMs were applied to spatially quantify the impact of humans on natural environment by estimating Japanese domestic Hidden Flows (HF). We found not only potential volume of HF by

comparing the respective results of bottom-up and top-down accountings, but also spatial distribution of anthropogenic disturbance. The results showed that from 1987 to 2005, DEM-based methodology may produce an overestimation of as much as 1.6%–6%, depending on the accuracy of the original DEM. In the bottom-up accounting, the total area of the anthropogenic disturbance, 170 million m^2 and volume of the anthropogenic disturbance, 5.8 billion m^3 which comprised the Domestic Extraction (DE) and HF. Top-down accounting, total volume of DE was 3.2 billion m^3. By comparing two results, we estimated the potential volume of domestic HF, 2.6 billion m^3 of mining sector. A special feature of this study was the use of a direct analysis of anthropogenic landform change to calculate material extraction.

In chapter 3, a methodology of automatic detection and measurement of anthropogenic disturbance at material extraction sites was developed. Using Japan as a case study, ArcGIS's Weighted Overlay Tool was used, a computational tool which can solve geographic multi criteria problems such as site selection and suitability model. The results suggested that ratio of unused extraction to used extraction may exceed 1:1 for construction minerals. We also found that the environmental effects of anthropogenic activity are bigger than natural soil disturbance by several orders of magnitude. The annual average volume of material removed by anthropogenic disturbance per area was thus about 3.1 m^3 /m^2 per year, while loss of surface soils by natural phenomena such as water flow or wind is 0.00028 m^3/m^2 per year, four orders of magnitude less than anthropogenic disturbance. And the mining and quarrying sites spread all over Japan, because of the low-cost and that were not transported over long distance to shorten the supply; mining and demand; urban area.

In chapter 4, dynamic of anthropogenic disturbance and its relevance to material flows such as DE and waste flows of Germany were discovered. Total area and mass of mining is 570 million m^2 and 15.3 billion tonnes, while total area and mass of filing is 390 million m^2 and 7.76 billion tonnes. In addition, location information of them may be useful for policy making, green business strategy design for manufacturing industry and mining industry, as well as for sustainable management of resource extraction and waste management. We also mentioned the existence of HF, which is used for backfill. HF such as waste rocks and overburden were regarded as no-economical materials, however, they have been used effectively to fill voids in material extraction site. We found mass of effective use of unused materials achieves 14.1 billion tonnes.

In chapter 5, Japanese and German anthropogenic disturbances were compared. The gap of annual volume per area of anthropogenic disturbance between Germany (0.85 m^3/m^2) and Japan (3.41 m^3/m^2) is 2.56 m^3/m^2, this would be caused by the difference of original national geography, type of mining, and sense of conservation of nature. The analysis of geographical features can contribute to assess the environmental impact of anthropogenic disturbance in a common framework.

In chapter 6, a summary of this study, findings and future works of anthropogenic disturbance were described. We also showed benefits for academics, industry, and policy-maker with possibility of developing common framework of monitoring anthropogenic disturbances. The DEM used methodology can be available in countries with poor statistics to develop of used and unused materials databases. Additionally, we mentioned necessity of another reliable and efficient methodology for global scale analysis in addition to three different methods (visual interpretation, automatic detection, and landcover), which were presented in previous chapters.

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氏　　名　吉田　圭介

論　文　内　容　の　要　旨

現代社会へ投入，廃棄される物質(以下，マテリアルフロー)および蓄積された物質(以下，マテリアルストック)は増加傾向を示し，建築物や社会基盤として，経済活動を支えるとともに，様々なサービスを提供してきた．持続可能な社会の構築に向け，マテリアルフロー・ストックが社会経済システムに及ぼす影響の解明が求められる一方，マテリアルフローの起点と終点にあたる自然環境へ与える影響の把握も同様に重要である．特に，資源採掘に伴う人為的撹拌は，統計では把握できない莫大な量の隠れたフローを生み出し，自然環境に対し不可逆的な破壊をもたらす．しかし，マテリアルフローが自然環境へ及ぼす直接的な影響に関する知見は十分ではない．本研究は，地理情報システム(GIS)および数値標高モデル(DEM)を活用し，人為的撹拌を観測する手法の構築，資源採掘量および隠れたフローの定量化，人為的撹拌に関わる動態の解明を行った．

第１章では，持続可能な社会へ向けた国際的な取り組みを紹介し，マテリアルフロー・ストックがもたらす人為的撹拌と，リモートセンシングを活用した人為的撹拌に関連する既往研究を整理した．

第２章では，ボトムアップ手法(GIS, DEM)およびトップダウン手法(統計)による日本国内の隠れたフローの推計手法，分析データ，分析結果を示した．また，資源の採掘に伴う隠れたフローの定量化に加え，人為的撹拌の空間分布を明らかにした．ボトムアップ手法の精度検証では，活用したDEMの精

度に応じ，1.6 - 6.0%の過剰推計が検出され，1987年から2005年にかけて，日本全国の人為的撹拌面積は1億7千万 m^2，撹拌量は58億 m^3 に及ぶことが判明した．一方，トップダウン手法を用いた結果，日本国内における対象期間内の土石系資源採掘量は32億 m^3 となり，日本国内の潜在的な隠れたフローは26億 m^3 に達することが明らかとなった．

第3章では，資源採掘に伴う人為的撹拌の自動抽出・推計手法の開発，及び，本手法による結果を示した．ArcGIS のアプリケーションである加重オーバーレイを活用した，日本全域に広がる人為的撹拌の分布が明らかとなった．DEM および統計データによる把握された資源採掘量を比較した結果，採掘された土石系資源量と隠れたフローの割合は 1:1 であることが判明した．また，自然侵食による土地改変量，0.00028 m^3/m^2 に対し，人為的な土地改変量は 3.1 m^3/m^2 に達し，人為的撹拌による膨大な環境への影響が明らかとなった．

第4章では，ドイツ国内における人為的撹拌に着目し，DEM および土地被覆を用いることで資源採掘量，埋立量，隠れたフローを推計した．2000年から2010年にかけて，採掘面積および採掘量は5億7千万 m^2，153億トンにおよび，埋立面積および埋立量は3億9千 m^2，77億6千万トンに達した．また，ドイツのマテリアルフローデータベースと比較することで，資源採掘に伴い発生した201億トンの隠れたフローのうち，およそ141億トンが埋め戻しに用いられたと判明した．

第5章では，日本とドイツにおける人為的撹拌の比較を行った．日本における一年あたりの人為的な土地改変量は 3.41 m^3/m^2 である一方，ドイツでは 0.85 m^3/m^2 であることが示された．人為的な土地改変量(2.56 m^3/m^2)に違いが生じた理由として，両国の地理的な特徴や資源採掘の形態の違いが考えられる．マテリアルフローの起点と終点にあたる採掘地，埋立地に関する動態を定量的，空間的に把握することで，持続可能な資源採取や，廃棄物管理に寄与すると期待される．

第6章では，人為的撹拌に関する結果と将来の研究概要を述べた。また，全世界の人為的撹拌を観測する手法，及び枠組みの構築に触れ，学術，産業，政策立案との関わりを示した．DEM を用いた本手法は，特に，統計データの整備が不十分な国・地域において，資源採掘，隠れたフローに関するデータベースの構築に貢献できると期待される．