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SOIL EXCAVATION AND LANDFILL: A SIGNIFICANT PROBLEM FOR CENTRAL THAILAND?

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INTRODUCTION

The use of soil landfill for urban construction, aimed at raising land above flood levels, is common in and around Bangkok. Fleets of ten-wheeler trucks, loaded with soil destined to in-fill low lying swampland, are a common sight. Until about eight years ago, the government of the day was beginning to recognize some of the environmental impacts associated with this activity and measures were being discussed about how to address it. The economic crash of 1997 effectively solved their problem by significantly reducing the work of the construction industry. With the recent upturn in the economy, however, soil excavation and landfilling is once again becoming an issue.

The objective of this paper is to make a preliminary assessment of the extent of soil excavation for use as landfill with some basic estimates of the areas and amounts involved. Some of the environmental impacts of these activities, both in terms of the areas where the soil is being taken from, as well as where it is deposited, will also be examined. A case study will be used to evaluate a number of different scenarios.

Land Transformations in the Central Plain

The central river basin area of Thailand is significant in many respects. It occupies about 35 percent of the country's land area, extending about 400 km to the north and in the widest part, 180 km east to west (ROUND *ET AL.*, 2001). It can be divided into the upper plain (>20 m a.s.l.) that has been settled and farmed for many centuries, and lower plain (average 2 m a.s.l.), that remained as relatively undisturbed swampland until the establishment of Bangkok in 1782. Today, about 30 percent of Thailand's population (20 million) live in the basin area, most of them making a living from farming, with the remainder (approximately 8 million) residing in Bangkok and the surrounding peri-urban areas (HUNSPREUG, 2000).

After Bangkok was established, much land and water resource development followed which were closely associated with intensive rice cropping for export. Further land transformations have since occurred through agricultural diversification, in the form of vegetable and fruit tree production. This has not only allowed more intensive use of the increasingly limited water resources, but has also spread the risks and helped to increase incomes, though such systems are also more environmentally polluting (KORPARDITSKUL & POSS, 2000). The rapid rate of such land transformations away from traditional agricultural practices, has also been compounded by increased levels of urbanization in many areas, linked with land speculation and increased demand from a growing population. In terms of the wildlife conservation value, the lower basin has been mostly transformed to other land uses with almost none of the original vegetation now remaining, though the area does retain important conservation attributes (ROUND *ET AL.*, 2001).

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Land Speculation

Throughout these decades of development, with the increasing financial benefits from the cultivation and export of rice, the economic value of land also increased (MOLLE & SRIJANTR, 1999). Infrastructure developments such as the Chao Phraya Project in the late 1950s and subsequent road developments led to significant land price hikes (HAFNER, 1970). A tremendous increase in demand for urban land in the 1980s started a land boom, with speculators using land for profitable investment, helping to fuel the bubble property market and economy. Bangkok land prices increased by over 200 percent during 1987–90 (POAPONGSAKOM, 1992). Such price hikes discouraged the use of land for traditional agricultural practices, such as rice in and around Bangkok, rather setting a trend for land transformation to other uses, with emphasis on urban expansion (HUNG & YASUOKA, 2000) as well as for highly intensive market gardening, orchids and even shrimp culture (MOLLE & SRIJANTR, 1999).

Land Subsidence

The lower plain area is a depression that has been filled in with different sediments throughout the Quaternary period, resulting in a complex of alternating sand and clay layers, varying in thickness from 400 to 1800 m and including aquifers (ESCAP Secretariat, 1988). Land subsidence in Bangkok, caused mainly by the excessive extraction of groundwater, has caused severe problems with some areas subsiding as much as one meter over the last 23 years (BONTENBAL, 2001). A number of benchmarks have been installed in and around Bangkok to monitor land subsidence (AIT, 1981). Areas particularly badly affected by subsidence are Lat Krabang and Samut Sakhon, with 4.75 and 3.0 cm decreases in land levels for 2000, respectively. The year of maximum land subsidence was 1979 for Bang Kapi, which subsided 12 cm in that year (BONTENBAL, 2001). There is a similar relationship with urban expansion in that when there is an economic boom, water extraction increases with the direct consequence of land subsidence. Such drops in the level of land, combined with the risks of flooding, justify the attention given to soil landfilling for construction. The long-term effectiveness of such a policy, however, has to be questioned and more emphasis ought to be placed on water conservation and reduced groundwater usage. Unfortunately, such schemes are riddled with problems of non-cooperation between government agencies and consumers (INCHUCKUL, 1999).

Excavation and Landfill Legislation

The current legislation governing the use of soil as a landfill is the Excavation and Landfill Act 2543 (MOI, 2003). This gives information on the amount of soil that can be excavated before permission is required, together with the penalties for non-compliance. Excavations that are less than 3 m deep and cover an area of less than 1 ha are allowed without permission from the local government. If this area or depth is to be exceeded, details are required regarding plans, methodology, transportation, responsible persons, and the related project (Section 2 Article 17). In relation to landfilling, projects that raise land levels above adjacent areas and which exceed 2000 m^2 in area require the installation of drainage systems (Section 3, Article 26). If the regulations are not followed, penalties range between fines of up to 50,000 baht (~US$1200) and one year in jail.

A Case Study: Pathum Thani

Pathum Thani Province, covering a land area of 1524 km^2, is situated in the heart of the lower Chao Phraya River basin area, adjacent to Bangkok City. It represents an area of rapid land use change with a strong trend towards urbanization (Table 1). Clearly, the predominant land use for the given baseline year of 1979 was rice cultivation which showed a dramatic decrease over the 20 year study period, with 11 percent of this being accounted for by urbanization. Other land use categories and transformations to urban areas are also shown in Table 1 giving a total urban or built up area of 35,143 ha (351 km^2) or nearly a quarter of Pathum Thani Province land area.

These land use changes have not however, been uniform and consistent. HUNG & YASUOKA (2000) describe a gradual increase only in the urban area for each of the seven provincial districts (range from 6–11% in 1970 to 7–18% in 1985), and a corresponding decrease in paddy area (from 82–92% in 1970 to 43–83% in 1985) up until the mid 1980s when there was a rapid increase in urban area up until the mid 1990s followed by a leveling off through to 2000 (range of 12–38%), partly related to the economic slump and partly due to in-fill development rather than further expansion.

Table 1. Estimation of land use changes (in ha) for Pathum Thani Province between 1979 and 1999. The figure in parentheses indicates the percentage change in land area compared with the baseline data of 1979. (Data adapted from HUNG & YASUOKA, 2000).

Land use category	Land use area		Area (and percentage) of land use category converted to urban (built up areas) from 1979 data.
	1979	1999	1999
Paddy	122,753	75,313	13,556 (11.0%)
Fruit tree plantation	3,225	1,616	303 (3.4%)
Vegetable production	2,184	417	816 (37.3%)
Fallow land	4,043	2,031	2013 (49.8%)
Water body	1,194	1,194	0 (0%)
Urban (built up areas)[1]	18,455	18,455	18,455[1]
Total urban (built up areas) in 1999			35,143

[1] There was no change in the 1979 baseline urban land use area, with additional urban areas being added from other land use changes (column 4).

Such land use changes and the processes involved with these have adverse impacts on the soil and environment. Depending on the area and the depth of the excavation site, soil quality will vary considerably both in fertility and depth, with topsoil being of better quality than subsoils. Inevitably, even with shallow excavations, a large proportion of the excavated soil used for landfill will be of the lower quality subsoil. For larger land development companies, contracts are agreed, with a set budget, for the completion of the landfill operation and there is no assessment of source or quality control of the soils used (T. BURAPATANA, pers. comm.).

The process of soil landfilling for construction begins with the clearance of existing vegetation, usually by backhoe and burning. A layer of sand 0.3 m deep, is then spread to assist with drainage, before soil is then dumped and built up across the construction site. This is spread, compacted and leveled by bulldozers. The required new level is usually between 1 to 1.5 m above adjacent land, but a further 0.3 m is added to compensate for subsequent settling. A period of a few months is usually allowed for settling before construction begins.

Calculation of Landfill Requirements and Associated Co-opted Area

If an area of 1 ha is to be in-filled with soil for construction to a height of 1.8 m (including the 0.3 m allowance for settlement to a final height of 1.5 m), the volume of soil will be 18,000 m^3 (i.e. 100 x 100 x 1.8). The bulk density of the soil is its mass (kg) / volume (m^3), in units of kg m^{-3}. Assuming that the settled bulk density at the in-fill site is 1,800 kg m^{-3} then the mass of the soil will be 32,400,000 kg which must be equal to the mass of the soil removed from the excavation site.

The bulk density of the original un-compacted excavation site is assumed to be 1,300 kg m^{-3} (typical of agricultural soils in this area). Assuming the original source site is excavated to the same depth as the increase in land level (1.8 m) at the in-fill site, then the volume and area of soil that is required from the original source site can be calculated as the mass of soil used for in-fill site (32,400,000 kg) / bulk density of soil of original site (1,300 kg m^{-3}) equal to 24,923 m^3.

Therefore, for an excavation depth of 1.8 m, the area of the original excavation site would be 13,846 m^2 (i.e. 117.67 x 117.67) compared with the new in-fill site of only 1 ha (10,000 m^2) representing an area 38 percent larger than the new 1 ha in-fill site.

Using a different scenario, if an average excavation depth of 20 m is assumed, then the area co-opted would be less, at 0.12 ha (35.3 x 35.3 = 1246.1 m^2), that is, only 12.5 percent (one-eighth) of the 1 ha landfill area.

In addition to such scenarios as these, there will also be a reduced potential of the land adjacent to the excavated hole due to the changes in the local hydrology, principally through decreases in available water either for crop production or for the functioning of a wildlife habitat. This figure (x below) depends on the soil hydraulic properties and would require further research to be fully assessed depending on soil type and location.

Soil excavation and landfill can also be considered from the point of view of amount of total land taken out of potential agricultural production (or other land use such as wildlife habitat). For example, soil which has in-filled an area will also bury the existing fertile topsoil, effectively stopping any further potential agricultural production from that area (ARIESEN, 2001). So, using the example of a 1 ha landfill site given above with an excavation depth of 1.8 m, the total area of land actually taken out of potential agricultural production is 2.38 + x ha, where x has to be determined on a case by case basis. This is calculated as the new in-fill site area (1 ha) + the original excavation site area (1.38 ha) + the land area affected by altered hydrology, x (variable), amounting to 2.38 + x ha in total.

If these figures are broadly extrapolated to the case study in Patum Thani Province, then for an area of 35,143 ha that had been urbanized in 1999, the soil excavation area co-opted for this would be 48,497 ha, not including the area affected by altered drainage (*x*). In the alternative scenario, if an excavation depth of 20 m is assumed, then the area co-opted would be less at 4,217 ha, again not including co-opted adjacent land with altered water relations. In reality, depths of excavations will be highly variable depending on local conditions, requirements and the legal agreements, with the figures presented here designed only to give a broad impression of the potential significance of such activities.

Table 2. Summary of the impacts of soil excavations and associated co-opted land.

Locality	Urban area considered (ha)	Depth of soil in-fill (m)	Depth of excavation (m)	Area needed for required soil volume[1] (ha)
1 ha (example size of a gated community in Bangkok)	1	1.8	1.8	1.38
1 ha (example size of a gated community in Bangkok)	1	1.8	20	0.12
Patum Thani Province (1999)[2]	35,143	1.8	1.8	48,497
Patum Thani Province (1999)[2]	35,143	1.8	20	4,217

[1] This is considered to be the area that has been co-opted in order to supply the required volume of in-fill soil to the given areas. This does not include the adjacent land affected by altered hydrology, i.e. *x*, as described in the text.

[2] See Table 1 for details.

Significance of Soil Excavation and Landfill

Areas from which soils are frequently excavated include Minburi, Nonthaburi, Patum Thani and Nakhon Pathom, though provinces further away from the primary landfill areas, have also been used. Obviously, soil excavation sites that are closer to the landfill area will be favored from the economic point of view in terms of transport costs, and this is probably reflected in price quotations from a sample of soil landfill companies, ranging from 60 to 600 baht per cubic meter of soil (T. KITISRIWORAPHAN, pers. comm.). However, it is assumed that after a time such premium excavation sights would become depleted and others at a greater distance would have to be used instead. An indication of the extent of soil excavation could be obtained from the number of companies operating, with for example 48 being based in Bangkok alone[1].

Excavation sites are frequently deeper than 3 m (the depth before permission is required by legislation), with P. SUWANIT (pers. comm.) reporting an average depth of 20 m, but also in a few cases excavations are as deep as 40 m. Natural restrictions that limit depth of digging, such as a high ground water table, can be overcome by pumping. Excavations for the purpose of obtaining sand are also common and follow the same principles as for soil excavations. Attention has been drawn to riverbed sand excavations in recent years, with particular reference to subsequent problems with water flow, but also in relation to the illegality of some operations and the lack of enforcement of legislation (e.g. Bangkok Post, 1998a, 1998b). In terms of soil excavation and in-fill, accurate assessments of what is actually happening on the ground need to be made. Analysis of legal documentation made between excavation companies and the local government may assist with this, though excavations that have not gone through the proper channels will not be apparent in such documentation and other data such as remote sensing with follow up ground surveys may be used in addition.

The hole remaining after soil excavation can no longer be considered for agricultural production. Even at shallow excavation depths, the exposed subsoils are not favorable for good growth of most crop plants. Other possibilities might include using the hole for aquaculture if water is available to fill the hole. In some cases, subsurface sand layers with low water retention properties have made water containment impossible (T. VEARASILP, pers. comm.). Using the hole for solid waste disposal will have inevitable consequences of waste seepage if not managed properly (possible illegal dumping), and might meet resistance in the local community.

Large holes tend also to affect the hydrology of the surrounding areas, since there will be drainage of surrounding surface and soil water into them, thus affecting the agricultural productivity of a wider area, and having potential repercussions on wildlife habitats such as wetlands. Hence the use of landfill has repercussions for a much wider area than the actual excavation area. If there is a high sand content in the soil being excavated, soil hydraulic conductivities will mean that a larger area will be co-opted since drainage will be greater. The impact of this on clay soils with lower hydraulic conductivities will be less but is nevertheless an important consideration. Further work is needed in areas specifically affected by such operations to make an accurate assessment.

There are also impacts on hydrology from the landfill areas, despite drainage systems being added to larger in-fill sites. The compacted nature of the in-fill soil reduces water infiltration and increases runoff, with this obviously being more pronounced for the concrete covered surfaces of new urban areas. There are also problems in the positioning and extent of the landfill area, both in terms of local drainage, but also in reducing the natural capacity of the lower plains to disperse flood waters (HUNSPREUG, 2000).

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[1]Detail of companies selling soils are available from the internet e.g. **www.yellowpages.co.th**, **www.thailandbuild.com** and **www.mweb.co.th**

Excavated holes can also be converted into other land use types. About ten years ago there was a fashion for developing small fish ponds for recreational use from excavated holes. In shallow excavation sites, ponds might also be created for growing lotus, though in a way similar to the intensive vegetable production systems, lotus cultivation is associated with high usage of pesticides (M. WATANASAK, pers. comm.), offsetting some of the potential wildlife conservation benefits from these new environments.

Although there is a need for soil excavation and landfill for construction, despite rapid land subsidence in many locations, there is no control over which soils are being used and the value these soils might have for long-term agricultural production, or for wildlife conservation. For example, an excavation site in Suphanburi province, which has some of the best agricultural soils in Thailand (the Kampengsaen soil series, MONCHAROEN ET AL., 1987) is rapidly being mined of its soil (T. VEARASILP, pers. comm.). A system of land zoning, which incorporates land evaluation, planning, and management would help to identify and preserve particular sites of importance, reducing the adverse impact of excavation activities.

Conclusion

The process and extent of soil excavation in and around the lower central plain of Thailand is not clear. This is due to a lack of information related to the selection and extent of areas used, compliance with and enforcement of legislation, licensing and regulation of companies and the implementation of reclamation measures of excavated sites. What does appear to be clear is that the process of soil excavation and landfill is a significant problem, in terms of the adverse impact it has on agricultural production, hydrology, and wildlife conservation.

This paper has presented simple calculations that demonstrate the potential extent of soil excavations and landfill using assumed soil properties and has extrapolated these calculations, using different scenarios, to a larger scale using Pathum Thani Province as a case study. Such an assessment can only be seen as a broad indication of the actual situation and the potential problems associated with it. In order to form a more accurate picture further information is needed about areas currently being used and the number of licenses issued, as well as prosecutions of people breaching the regulations, with associated details. Land evaluations should also be made using soil maps and land capability data base systems combined with remote sensing technology. Such work will allow for a more accurate assessment to be made of the impact soil excavations and landfilling are having on the natural resource base of the lower plain.

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